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Cantor Lectures

ON THE

MODERN METHODS OF ARTIFICIAL ILLUMINATION.

BY

LEON GASTER
(Editor of the "Illuminating Engineer.")

Delivered before the Royal Society of Arts on February 15, 22, *and March* 1 *and* 8, 1909.

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LONDON:
PRINTED BY WILLIAM TROUNCE, 10, GOUGH SQUARE, FLEET STREET, E.C.

1909.

Price Two Shillings.

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MODERN METHODS OF ARTIFICIAL ILLUMINATION.*

LECTURE I.—DELIVERED FEBRUARY 15, 1909.

ELECTRIC LIGHTING.

INTRODUCTION.

When I consider the long list of distinguished predecessors who have delivered Cantor lectures before the Society, I need hardly say that I greatly appreciate the honour and privilege of delivering this series on "Modern Methods of Artificial Illumination."

It is, I think, peculiarly fitting that the Royal Society of Arts should take an interest in this subject, for it may truly be said that, in the past, they have encouraged the development and utilisation of all illuminants in an impartial manner such as, perhaps, no other Society in this country can claim to have done. They have invariably presented an opportunity for the discussion of all methods of lighting from the candle to the glow lamp, and many years ago they had already offered prizes for the invention of miners' lamps, lighthouse apparatus, and other practical developments in lighting. Over 100 papers have already been read before the Society dealing with various aspects of the subject with which I am concerned in these lectures.

As early as 1874 Cantor lectures were delivered by Prof. Barff, M.A., on carbon for heating and illuminating purposes. Again, in 1881, Prof. W. Grylls Adams, F.R.S., delivered Cantor lectures on the scientific principles involved in electric lighting, while in 1883 Mr. Leopold Field, F.C.S., lectured on solid and liquid illuminating agents.

The Cantor lectures by Prof. Vivian Lewis on acetylene, and also on the theory of the incandescent mantle, &c., undertaken at a time when these subjects had begun to interest the general public, and Prof. Sylvanus Thompson's exhaustive Cantor lectures on "Arc Lamps," are again illustrations of the enterprising and impartial policy of the Society.

In 1881, Dr. R. Brudenell Carter delivered a series of Cantor lectures on the subject of colour blindness. In that lecture, and in the subsequent valuable communications of the same author on the subject of eyesight, indications are furnished that the Society was early alive to the importance of drawing attention to the preservation of the eyesight of the public, and its important connection with good illumination.

Naturally, in the short time at my disposal, I cannot hope to deal exhaustively with each special department of the subject of illumination so as to furnish information to the expert in his particular line; my aim and object will be rather to cover the ground in a general manner, and to show how it is possible to take an impartial interest in all systems of lighting, and to emphasise the true merits of each illuminant for different purposes.

I may, however, preface my discussion of this subject by a few remarks on the development of illumination in general. The introduction of gas for street lighting for instance, dates from about 100 years ago. Previous to this time we had recourse to oil lamps, and it is even said that bowls of pitch were used to light the streets of Paris in the sixteenth century.

At the same time the use of lamps for interior lighting was likewise in a very primitive state. In those days the expression "The night when no man can work" had a very real significance which we can hardly conceive to-day. Now, in the present age, the tendency is to do more and more work by artificial light and to turn night into day with an ease our forefathers might or might not have envied, but certainly would have regarded as incredible. Step by step with these developments in lighting have taken place the progress of education and the spread of printed matter, until, to-day, we use our eyes for the purpose of acquiring knowledge to a far greater extent than in the times when neither education nor adequate illumination was generally available.

* The Course consisted of four lectures, delivered on February 15th and 22nd, and March 1st and 8th. In rearranging the material for publication in the *Journal*, the lecturer has preferred to divide it into six parts.

In the same way the eye is more used in education than was previously the case. No lecture is now considered complete without the exhibition of a few lantern slides, while recently such special appliances as the cinematograph have also been put to the service of education.

We ought, therefore, obviously to consider not only the actual light we produce but its effect under practical conditions—the actual illumination in which we are mainly interested, and for which we are really paying. Expressing the matter epigrammatically we may say "light is the cause, and illumination the effect."

I dwell on these points but briefly in this present lecture, meaning to return to them in greater detail later on, but I would ask you to bear the situation in mind when I go on to mention some other developments in the quality of lighting that have given rise to important changes in industrial conditions. Viewing the subject from this aspect we are bound to realise that illumination is first and last dependent on the physiological impressions from the eye. Into this point, too, I do not wish to enter too closely in the present lecture; it seems, however, a little singular that this obvious fact has not hitherto been very generally realised among engineers, who are at the present time mainly responsible for the generation and distribution of light.

Simultaneously with this enormous progress in the amount of light available has proceeded a remarkable development in our powers of modifying its quality.

Returning to our earlier sources—the camp fire and the charcoal brasier—we see that the light thus obtained was of a distinctly reddish character; afterwards came the pine torches, still very red, then candles and oil lamps, which are whiter. Later still the introduction of gas provided light of a still lighter tint, and, indeed, we have records of objections to it on this score when it was first introduced. The incandescent mantle and the electric light have now provided sources of light that are whiter still.

Now this change in colour corresponds with a very natural development in the temperature of incandescence obtainable, for all the sources named depend for their action on the heating up of solid particles. In civilisation we have passed through a similar process to that which takes place when we heat up a piece of iron. At first we merely obtain a jumble of radiations of long wave lengths, none of them capable of giving rise to the succession of light. As we go on heating we eventually perceive a faint red glow corresponding to the low vibrations, and then this glow develops a yellowish and eventually even a whitish character.

Yet we know that by heating solids in this way, we must always obtain only a confused forced vibration of the mass as a whole, and therefore relatively few rays of the luminous variety. Still more recently, however, we have learned how to employ luminescent gases in which the natural frequency of vibration of the different particles is utilised so that we obtain only vibrations of certain specified frequency, and a corresponding peculiarity in colour, certain rays being often absent, which exist in the normal spectrum of an incandescent solid. An illustration of such methods is afforded by the mercury vapour lamp and the flame arc.

These I mention, merely in order that you may bear in mind that the change in methods of illumination, to which we are now becoming accustomed, is one not only of quantity, but also of quality, and therefore requires correspondingly careful study, in order that we may know how the new conditions may be utilised to the best advantage.

After this preamble, I may now turn to the consideration of recent developments in electric lighting, and I think that a fitting introduction to these new illuminants is provided by the following abstract of Mr. Swinburne's Presidential address before the Institution of Electrical Engineers in 1902:—

"Our chief work, until lately, has been producing light. Here the inefficiency and waste is prodigious, and there is still great room for improvement. We take great care over our stations, watching every penny from the coal shovel or mechanical stoker to the station meter. We quarrel over 1 per cent. in the generators. When we get to the mains we care less, and once we get to the customers' meters we care nothing at all."

Since the date of Mr. Swinburne's address we have seen a wonderful development in electrical illuminants. We have seen great progress in Flame Arcs, Metallic Filament lamps, not to mention the Mercury Vapour lamps, and the Moore Vapour tube.

We have also seen a great change in the method of regarding the utilisation of the light we have been at such pains to produce, and the partial realisation of the true significance of the word "Illumination." As an amusing illustration of this fact let me mention the experience of a friend who had the curiosity to look up the word "illumination" in an

encyclopædia. He was rewarded by the cryptic reference, "Illumination—see fireworks."

Glow Lamps.

It may seem strange to reflect that from about the year 1878, when the first practical incandescent lamps were introduced, until a few years ago, when metallic filament lamps came upon the scene, the actual construction of the carbon filament lamp should have remained essentially the same. Yet we must remember that there were wide gaps in our knowledge of the materials available for the manufacture of the filaments of these lamps which have since been utilised so successfully; these gaps had to be bridged before the newer material could be turned to practical account.

In addition, as M. Blondel has shrewdly remarked, there were several misconceptions which inventors did not learn to avoid. It was, for instance, generally supposed that all that was necessary was to find a substance with a very high melting point, and therefore capable of being carried to a very high temperature of incandescence. Actually we know now that this is a desirable quality in filaments, but at the same time we also know that the carbon tends to vapourise at temperatures very far below that at which it actually melts, and it is this tendency which imposes a practical limit on our possible temperature.

By bringing a carbon filament lamp to incandescence at a voltage higher than that at which it was intended, we could obtain a corresponding increase in efficiency, but only at the cost of its durability and life—long before the melting point is reached the volatisation of the carbon sets in and brings the filament to a premature end. What was really wanted, therefore, was a material that only began to vapourise in this way, and therefore to disintegrate at a temperature above that utilised in the carbon filament lamp.

Nernst Lamp. — Regarding the Nernst lamp, which deserves the credit of being one of the earliest commercial attempts to increase the efficiency of incandescent lamps to any great extent (it was introduced about 1897), I have not at my disposal any very novel data which can be made public. It may be said, however, that experiments are in progress with the object of making the filament in such a way as to enable it to "light up" more quickly without the necessity of the inconvenient heating coil and its additional complications.

The Electrical Company have now put on the market an improved form of Nernst lamp of specially small design, in which the four parts of the original Nernst lamp, namely, the body, burner, resistance, and globe are now combined into one unit.

The 220 volt lamp is stated to yield 30 candle-power and to consume abont 0·2 ampères, the efficiency being thus about 1·4 watts per candle. Improvements in manufacture enable the lamp to light up in, approximately, 10 to 15 seconds after switching on the current, and the life of individual lamps under normal conditions is stated to be not less than 400 hours. The average life of a burner has, however, been found to exceed 700 hours. I understand that the company undertake to replace free of charge any lamps which are burnt out under the specific period of 400 hours. The lamp is manufactured for all voltages from 200 to 300, but for the present they are only recommended to be used on direct current circuits.

By the kindness of the Electrical Company, however, I am also able to show you to-night one of the most recent developments in these lamps, namely, a 200 volt, 1,000 candle-power lamp utilising three glowers.

The Osmium Lamp, introduced about 1898 by Auer von Welsbach, to whom we also owe the incandescent mantle, is interesting as being one of the first of the commercial metallic filament lamps of recent date. There were, however, many difficulties in its manufacture—notably its brittleness, and the inability to make lamps for higher pressures than 50 volts—which hindered its development, and the lamps have been practically superseded by others to-day.

Filaments of *iridium*, a kindred metal, have been constructed by Gülcher. Here again, however, it seems to have been found very difficult to make lamps for reasonably high pressures, and the use of such filaments seems to be confined to low voltage lamps for accumulators on motor vehicles, &c.

The Tantalum Lamp, as you know, consists of drawn wire composed of the metal Tantalum. The consumption of the lamps now on the market, of which you will see some illustrations (kindly supplied by Messrs. Siemens and Co., Ltd.), varies from about 1·8 to 2·2 watts by candle.

To this Company also belongs the credit of having produced a 16 candle-power metallic filament lamp working at 100 to 130 volts., and a 32 C.P. lamp on 200-250 volts. I am given to understand that still further de-

velopments will follow shortly. The useful life of the lamp under normal conditions can be taken as about 800 hours. I will refer, in a later part of this lecture, to the behaviour of Tantalum filaments on alternating currents circuits.

There have, however, not been wanting experiments having for their object the improvement of the carbon filament lamp.

Graphitised Filaments.—You are probably acquainted with the researches of Mr. Howell in the United States (Proc. Am. I. E. E. 24, p. 617, 1905) who by a special process succeeded in making a so-called graphitised filament capable of giving a satisfactory light at a consumption of 2·5 to 3 watts per candle. The behaviour of these filaments suggests that we are dealing with an allotropic form of carbon in which it approximates to the qualities of a metal having a positive temperature co-efficient under normal conditions. Had it not been for the immense development of the more efficient metallic lamps, this marked advance would have received more attention than it actually has done.

Filaments of Soot, special Carbon Filaments, &c. — Experiments in this direction are still proceeding, and I observe that two German inventors claim to have succeeded in making a peculiarly homogeneous carbon filament from soot produced by the carbonisation of vegetable oils, and also from the materials used in Chinese ink. For this filament a useful life of 1,000 hours with an efficiency of 1 watt per candle (Hefner) is claimed.

The Hopfelt Lamp.—Another interesting attempt to run carbon filaments at an increased efficiency is due to Hopfelt (E.T.Z., Oct. 8th, 1908, *Illuminating Engineer*, vol 1, p. 631) who has utilised a carbon filament burning in an atmosphere of mercury vapour. It is claimed that the high pressure of the latter reduces the tendency to disintegration on the part of the filament, and therefore enables us to run at a consumption in the neighbourhood of 1·5 watts per candle.

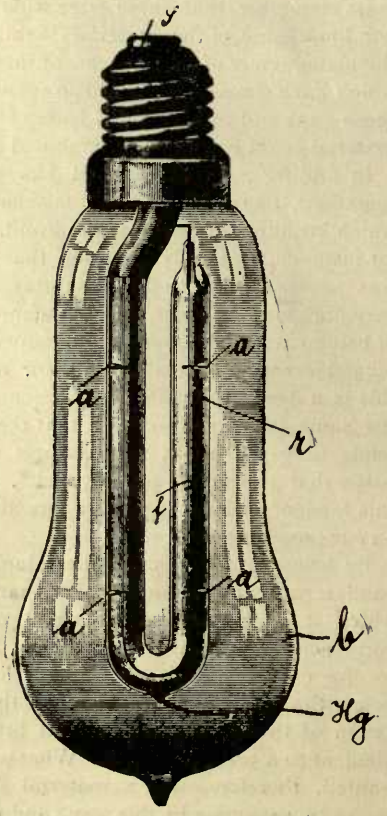
It is too early to speak of the possible developments of this method. I have, however, a few here on exhibition in order that you may judge for yourselves.

Since writing the above I observe that a more complete study of this lamp has been published by U. Bordoni ("Atti della Assoc. Ellettrotecnica Italiania," March-April). He, however, describes researches according to which the lamps examined had but a small life.

The Helion Lamp.—An interesting type of lamp is that brought out by Parker and Clark in the United States, termed the "Helion" lamp.

The filament of this lamp is supposed to consist mainly of silicon, which is deposited by a special method on a carbon core. M. Blondel has advanced the suggestion that this may form an eutectic alloy with the carbon (Congrès de Marseille, 1908).

FIG. 1.



HOPFELT MERCURY-CARBON GLOW LAMP.

f, filament; *a*, *a*, *a*, supports for filament; *Hg*, globule of mercury; *b*, outer bulb; *r*, inner tube containing filament.

For this lamp it is claimed that a life of over 1,000 hours, at an efficiency of one watt per candle-power, coupled with practically no diminution in intensity is obtained; at the same time all the advantages of a high resistance filament are said to be secured. More recently still, the inventors claim to have improved the filament sufficiently to enable it to be burned in the ordinary atmosphere without any vacuum; they also state that it can be overrun to a very considerable extent without suffering thereby. (*Elec-*

trical World, N.Y., September 5, 1908). In spite of the excellent results recorded, however, we are still waiting for these lamps to be put upon the market on a commercial scale.

Tungsten Lamps. — There are now very many forms of Tungsten lamps on the market. They are called by different names and made by several distinct processes, but although the actual materials are believed to be subject to a slight modification in the case of different firms, it seems to be generally agreed that the metal tungsten is the basis of their composition. The actual processes of their manufacture are, however, extremely complicated, and I cannot hope to attempt to describe them on this occasion.

I should, however, like to refer to those who desire more complete details to a recent paper by M. Blondel (Congrès de Marseille, 1908) and to articles by Dr. H. Weber and Dr. F. Jacobsohn (*Illuminating Engineer*, London, vol. i., pages 297, 395, 463), in which some very complete data are given. It may, however, be said that there are at least three distinct chief processes. According to the first the metal is reduced to an "impalpable" powder, mixed with some adhesive binding material, and squirted through a very fine die. Subsequently all traces of the foreign binding material are very carefully removed, leaving only the pure metal, the filament being also brought, by a special process, from the non-conducting into the conducting state.

It is wonderful that such good results should have already been accomplished when we consider that filaments so made really consist of a collection of fine disjointed particles fused together.

Another process consists in the deposition of tungsten upon a carbon filament which is brought about by incandescence in an atmosphere of volatile tungsten compounds so that the tungsten gradually replaces the carbon; subsequently by special processes, the last traces of carbon are removed.

Yet another process is the well-known colloidal process of Kuzel, according to which metals are reduced to a special gelatinous condition, such that they can be squirted into filaments without the admixture of a binding material; in this way the arduous process of subsequently removing all traces of impurity introduced are avoided. These lamps have been sold in Vienna under the name of "Sirius," and are to-day sold in London by Messrs. Falk, Stadelmann and Co., Ltd., as the "Sirius-Effesca" lamp.

Although we must admit that most of these methods originated in Germany and Austria, we can comfort ourselves with the reflection that much of the early pioneer work of electrical glow lamps was carried out in London. At the present day too, I am happy to state that the manufacture of these lamps is being taken up in the country. To-night there are on exhibition different types of metallic filament lamps as supplied by Messrs. Boddy and Co. (the Metallik), The Bryant Trading Syndicate, The British Thomson-Houston Co., The Edison and Swan United Electric Light Co., The Electrical Co. (Aegma), Messrs. Falk and Stadelmann, Ltd. (Sirius-Effesca), the General Electric Co. (Osram), The Stearn Electric Co., The Sunbeam, the Westinghouse Co., and the "Z" Electrical Syndicate. Lamps are also sold under the following names, among others, in this country: — Simplex, Meta, Empire, E.M.F., Gral, Z., Auriga, Metfil, Tangent, Metalite, Rugby, Gabriel, Solium, Omega, &c. This will serve to furnish some idea of the choice of lamps available, some of which are now manufactured entirely in this country.

Some qualities of the metal filament lamps of interest are those given by Remané ("Verb. Deutsch. Elektrot.," 1908), and by Satori in a recent article in the *Illuminating Engineer* (Vol. II., p. 386).

As you will understand from these curves (see Fig. 2), there is no physical impossibility in obtaining a consumption of even less than 1 watt per candle-power from the ordinary carbon filament; but you will also observe how rapidly its life is decreased by doing so. The same holds good for the Tungsten lamp, as this diagram clearly shows. It is, however, worth knowing that, now that carbon filament lamps are so cheap compared with the most efficient metallic ones, it may sometimes be advisable to overrun them intentionally at, say, 2·5 watts per candle, so as to obtain a higher efficiency, even coupled with a loss of life. This point has been dwelt upon by a correspondent of the *Illuminating Engineer* (Vol. I., December, 1908, Vol. II., January and February, 1909).

But let us ask ourselves what disadvantages the new lamps already possess, and what prospects of improvement we see before us. In reality, when one follows closely the immense technical difficulties with which the manufacturers of metallic filament lamps have been confronted, one can only marvel at the ingenuity with which they have overcome obstacle after obstacle. One of the main problems has

been, and is still, the production of a metallic filment lamp of high voltage and low candle-power.

Thus the production of a Tantalum 220 volt 50 candle-power lamp is said to involve the use of wire of a diameter of only 0·04 m/m, and it is a miracle of ingenuity to draw homogeneous wire so fine. Yet Tantalum 250 volt 32 candle-power lamps are already on the market.

An Osram 220 volt 50 candle-power lamp involves a filament of the same order of diameter, coupled in both cases with an extraordinary length of filament.

Several lamp makers now announce that they are in a position to supply 200-260 volt lamps of as low a candle-power as 25-30 candles.

In the United States a 25 watt 100 volt Tungsten lamp has already been produced. As an illustration of the difficulty of this process I may mention that it takes a man a week's careful work even to make the die through which such filaments are forced.

Since the delivery of this lecture I notice that several makers have already brought into the market 16 candle-power, 100-130 volts metallic filament lamps rated at a consumption between 1 and 1½ watts per candle. Indeed, within the last few weeks the announcement has been made that the Stearn Co. are producing a 200 volt, 16 candle-power, 25 watt lamp. Simultaneously with the improvement in this respect a great reduction in the price has also taken place. I cannot help feeling, as I have already previously pointed out, that it would have been far better if manufacturers devoted their efforts to improving the lamps they have already put on the market, instead

FIG. 2.

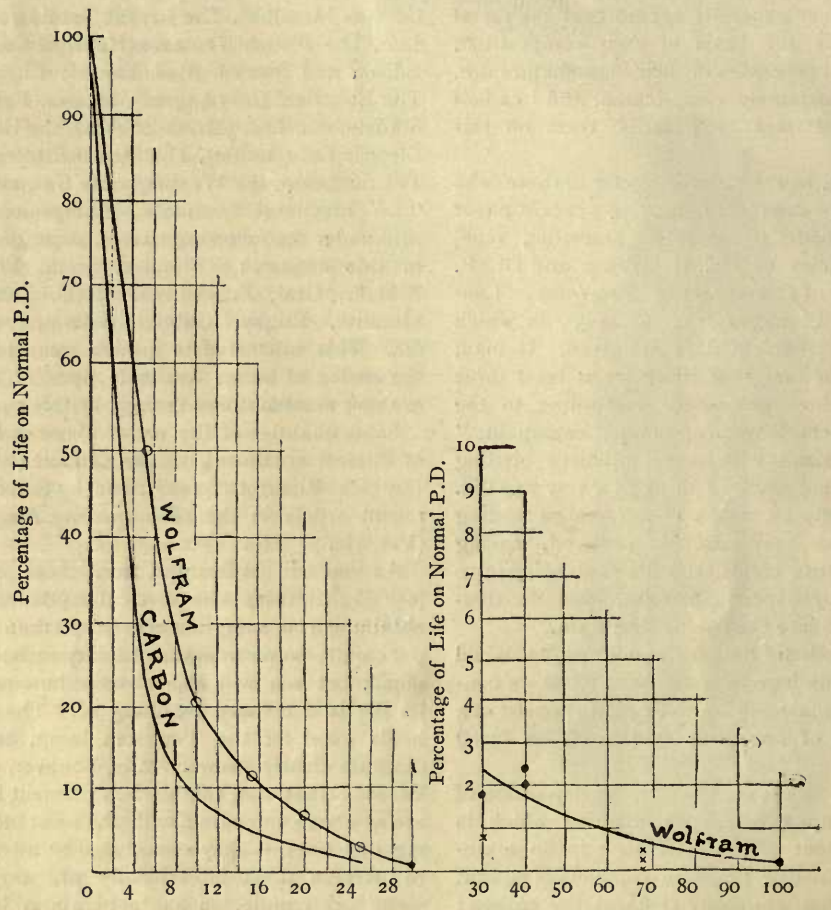


DIAGRAM ILLUSTRATING EFFECT ON LIFE OF OVERRUNNING CARBON AND TUNGSTEN FILAMENT LAMPS. (Satori, *Illum. Eng.*, London, Vol. II. June, p. 386.)

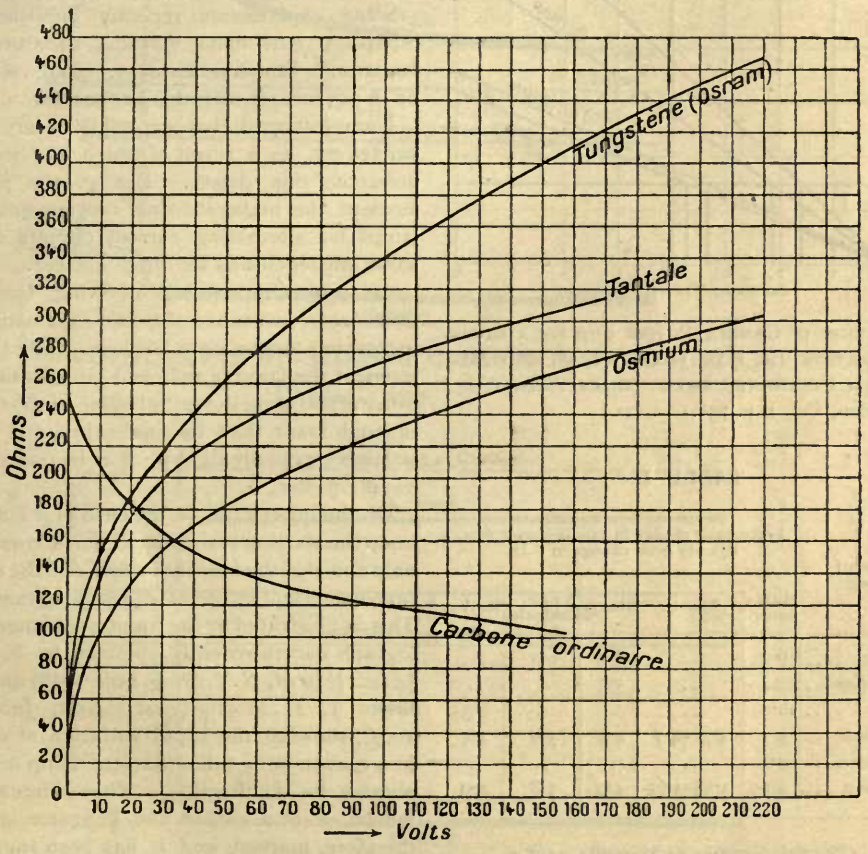
of expending misplaced energy in cutting one another's prices. If by the united action of lamp makers and dealers the prices were kept at a steady figure, giving a substantial margin of profit, funds would then be available for adequate experiments with the object of improving the quality of lamps. Progress will naturally be hindered by forcing the pace and supplying an indifferent article simply to meet competition.

fortunate because of the extremely disturbing effect upon the electric industry which would follow the sudden introduction of, say, Tungsten lamps capable of giving only eight candle-power at one watt per candle at 250 volts.

As I have pointed out previously, the present state of things serves to enable us to tide over the inconvenient transition.

Another quality for which metallic filament lamps are remarkable is the fact that their

Fig. 3.



Connection between Resistance and Pressure of Carbon Filament, Tantalum, Osmium, and Tungsten Lamps. (Blondel, Congrès de Marseille, 1908.)

It is also gratifying to observe that the bulbs of some types of metallic filament lamps are now about the same size as those of carbon filament lamps, so that the original fittings and shades can be used upon replacing carbon lamps by these new types.

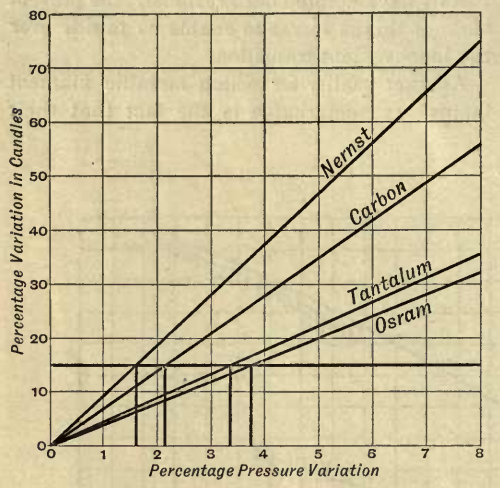
The difficulty in making high voltage low candle-power metallic filament lamps rests, of course, mainly in the very low resistance of the filaments compared with carbon. Yet, from one point of view this defect may be regarded as

resistance, unlike that of carbon, increases with temperature; this is indicated in Fig. 3.

Partially owing to this change in resistance we find that a given change in pressure produces a smaller corresponding change in candle-power in the case of metallic filament lamps than in the case of carbon ones. This is advantageous because it may enable the amount of copper in a consumer's leads to be reduced since the thickness of such leads is determined by the fall in pressure allowable up

to lamps. (Fig. 4.) Some details of the behaviour of different types of lamps in this way is shown in Fig. 4 and Table I.

Fig. 4.



VARIATION IN CANDLE-POWER DUE TO A GIVEN VARIATION IN P.D. FOR CARBON AND METALLIC FILAMENT LAMPS. (Bohle, *Illum. Eng.* London, Vol. 1, p. 738.)

TABLE I.

Type of Lamp.	Percentage change in candle-power due to 1 per cent. change in P.D.				
	Hirschhauer.	Morris.	Sharp.	Lab. Centrale.	Bohle.
Carbon	6·3	..	6·5	6·0	7
Graphitised..	..	..	5·5	..	..
Nernst	10·0	..	..	..	9·35
Tantalum ..	4·3	4·37–4·7	4·4	3·9	4·4
Osmium	4·2	..	..	..	..
Tungsten ..	4·0	3·36–3·65	4·0	3·8	4·0

(Blondel, Congrès de Marseille, 1908.)

Percentage change in candle-power due to 1 per cent. change in P.D. in the case of carbon, graphitised, Nernst, and metallic filaments.

On the other hand there is a second effect to be considered. Metallic filament lamps have a lower specific heat than carbon ones and consequently the filaments grow hot and cold with greater rapidity. As a result their momentary physical condition fluctuates to a greater extent when the voltage applied to their terminals varies and, possibly on this account, metallic filament lamps do not give quite such good results on alternating currents as on direct currents. The Tantalum lamp, as is well known, has not as yet been much employed with success on an alternating current circuit. I have been informed by Dr. Feuerlein that this is to be attributed (among other effects) to the attractive action of adjacent filaments on one another.

This gives rise to a continual mechanical trembling, and Tantalum has a property, common to the iron group of metals, of rapidly becoming crystalline under these conditions.

Some experiments recently published by Scarpa ("Atti della Assoc. Elettrotecnica Italiana," January-February. 1909), seem to be in agreement with this suggestion.

I am informed that experiments are being carried out as a result of which it is hoped to overcome this defect. But at the present moment the makers do not recommend these lamps for alternating current circuits at the same efficiencies as for direct current.

An interesting result following from the decrease in resistance of metallic filaments with increasing temperature becomes evident at the moment the lamp is switched on. In the case of a carbon lamp the initial value of the current is much lower than its final value, and we see a lamp gradually light up if it be one of high candle-power.

On the other hand, in the case of a Tungsten lamp the starting resistance is much lower, say, only one-eighth of its final value, and the instantaneous current is, therefore, eight times as high. This is illustrated by the tracings of some oscillograph curves recently obtained by Freeman (*Elec. World*, N.Y., Aug 15th, 1908) and Professor J. T. Morris (*Electrician*, June 7th, 1907), showing the rapid variation of current in a carbon or metallic filament lamp before it obtains its final value. The difference in behaviour of a carbon and Tungsten lamp is, therefore, marked, and it has been suggested that the occasional habit of metallic filament lamps of burning out the moment they are switched on is due to this effect.

One interesting type of lamp recently brought out in Germany contains a small carbon filament in series with the main Tungsten filament (see B. Duschnitz, *Illuminating Engineer*, Vol. I., page 817). This is shown in Fig. 6.

By this means the inconveniences resulting from being obliged to make a filament perhaps a thousand millimetres long and 0·03 millimetres in diameter, as is necessary in the case of a 220 volt 32 candle-power lamp, are partially avoided, for the small carbon filament

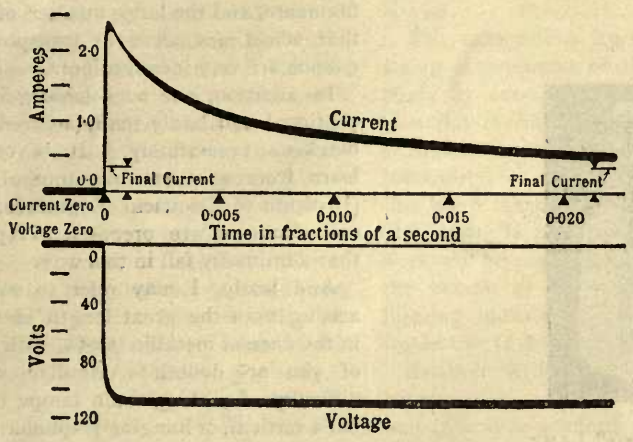
supplies the required resistance and enables us to secure a lamp which consumes about 1·5 watts per candle, and yet absorbs less actual current than the 16 candle-power carbon filament lamp.

An incidental advantage in these lamps is that the high cold resistance of the carbon filament prevents the initial rush of current characteristic of metallic filament lamps to some extent, the instantaneous current, during switching on, being only twice its final value. This lamp I have here on exhibition. (Fig. 6, p. 14.)

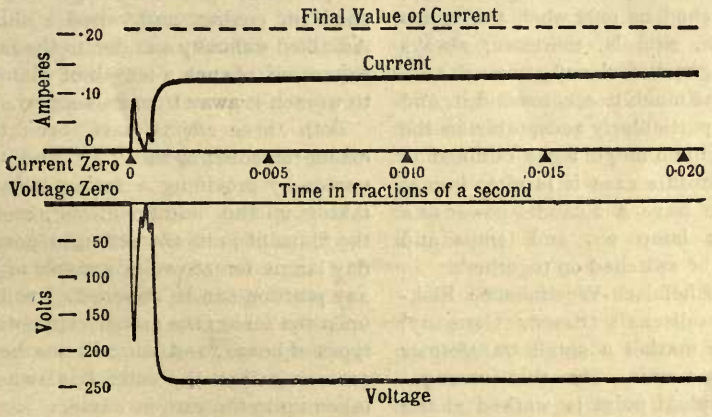
Transformers.—The mention of this lamp brings to mind another development in metallic filament lighting which has caused considerable interest, namely, the use of Tungsten lamps with a transformer. If an alternating current P.D. of, say, 200 volts be transformed down to 25 we are enabled to get all the advantages of the short and stout low voltage Tungsten lamp, the metallic filament being peculiarly well adapted for low voltages, and we have also the incidental advantage of much greater safety.

On the other hand, this system certainly can not be applied indiscriminately, partly because of the high initial cost of the transformer and

FIG. 5.



—OSCILLOGRAM OF STARTING CURRENT IN A 110 V. 32 C.P. OSRAM LAMP.



—OSCILLOGRAM OF STARTING CURRENT IN 220 V. 5 C.P. CARBON FILAMENT LAMP.

ILLUSTRATING GROWTH OF CURRENT THROUGH CARBON AND TUNGSTEN FILAMENT LAMPS WHEN SWITCHED ON. (Prof. J. T. Morris, *Electrician*, June 7th, 1907.)

expense entailed in the substitution of lamps of the lower P.D., and partly because it is very wasteful to have a transformer in action continuously if only a few lamps are switched on. These drawbacks have been to some extent got over by the introduction of automatic switches which cut the transformer out when no lamps are on the circuit. M. Weissman has also

FIG. 6.

THE "ECONO" LAMP.

recently developed the method of applying a small transformer to a special group of lamps, so that it is switched on only when the lamps are switched on, and is, therefore, always working at its highest efficiency.

This system has much to recommend it, and has been found particularly acceptable in the case of lighting illuminated signs outlined in glow lamps, for in this case it is often immaterial whether we have a 2 candle-power or a 16 candle-power lamp on, and lamps and transformer can be switched on together.

Recently the Rheinisch-Westfalische Elektro-Sparlicht Gesellschaft (Essen, Germany) have put on the market a small transformer and lamp in one unit. By this arrangement each individual point is worked at the highest efficiency. The transformers are constructed to take only one size of lamp, and this non-interchangeability makes it impossible to place a bigger or smaller lamp in the same socket. The introduction of this combined unit has much in its favour in those localities in which electricity is supplied, at a fixed charge per point installed in the building. The above system enables central stations to keep a control over a consumer who might otherwise try to change the size of the lamp for which he is charged for one of a higher candle-power. However, it remains to be seen how far progress in the direction of making high voltage low candle-power lamps will render the use of transformers superfluous.

Other Drawbacks of Metallic Filament Lamps. — There are still a number of defects of more or less consequence affecting the Tungsten lamps. For instance, it must be realised that the fragile nature of their filaments, and the large number of breakages that sometimes occur in transport in consequence are very inconvenient.

In addition, one occasionally finds an exceptional and badly manufactured lamp that blackens prematurely. It is consoling to learn from a recent utterance of Mr. Hirst (Institute of Electrical Engineers, 1908) that manufacturers are prepared to replace lamps that admittedly fail in this way.

And lastly, I may refer to one difficulty, arising from the great length of the filament in the case of metallic lamps, with which most of you are doubtless familiar, namely, the difficulty of making such lamps burn in any but a vertical, or hanging position. At one time it was found that any lamp burned in a horizontal or even an inclined position suffered because the filaments softened with increasing temperature, tended to sag, and ultimately came in contact and raised a short circuit. An allied difficulty was due to the fact that the expansion of such a length of filament tended to wrench it away from its support.

Both these effects have been to a large extent remedied by the "Z" and other companies by providing a spring loop capable of taking up this additional sag, and retaining the filament in its correct rigid position. To-day lamps for 200 volts capable of burning in any position can be obtained. I will now throw upon the screen the actual filaments of several types of lamps, and you will see how the sag occurring when the current is switched on, is taken up in the various cases.

I have dwelt upon the subject of glow lamps as far as time permits me to do on the present occasion; for further details I can only invite you to inspect the actual specimens on exhibition, and to make enquiries of the representatives of the various makes who are present to-night.

CONDITIONS OF LAMP INDUSTRY IN THE UNITED STATES AS COMPARED WITH THOSE IN THIS COUNTRY.

Before leaving the subject, however, I would like to comment on one respect in which the practice in the United States differs very

greatly from that in this country. Over here we have, as you know, many quite distinct makers, but mostly importers and dealers of lamps all competing against one another, and all claiming very special and peculiar merits for the particular types of lamps they represent. At the same time we have central stations all over the country employing a marvellous variety of pressures and other conditions of supply, and feeling very dubious as to the exact influence of the introduction of the new lamps on their revenue. The natural result has been that the central stations and the metallic lamp manufacturers do not co-operate to any extent and do not work in harmony. A particular illustration of this is furnished by the difference in the pressure at the consumer's terminals even in large districts in London. It is not only that the declared pressure varies, but it is also a fact that the latitude which the central stations allow in this nominal voltage also fluctuates very greatly.

Permissible Variation in P.D. at Consumer's Terminals.

The voltage, for instance, may be nominally 200, and yet actual records may show that it is near 210 or even 220 during a section of the night, and this notwithstanding the fact that it is clearly laid down by law that the pressure at the consumer's terminals should not fluctuate by more than plus or minus 4 per cent.

It need hardly be pointed out how unfair this is to the lamp maker, who, if he supplier lamps correctly graduated to suit nominas voltage, soon finds that the life of the lamps supplied gives rise to much complaint.

At a recent meeting of the Institution of Electrical Engineers (discussion of Paper by Mr. C. Paterson, 1907) one of the speakers commented on this difficulty, and let us into a secret of one method of trying to meet it—which will receive our sympathy, if certainly not our entire commendation—of supplying lamps marked for the nominal voltage, but really suited to the average actual value likely to occur in that district.

Instances of Co-operation in the United States.

In this connection I would like to draw your attention to the work of the National Electric Lamp Association in the United States. All the chief lamp makers in that country, who are, however, comparatively few in number, belong to this Association, which supports a laboratory for the purpose of carrying out common tests on glow lamps for the common benefit. In addition, the lamp makers are in constant co-operation with the central station who, indeed, very generally actually supply lamps to their customers, and who, therefore, are in a position to advise them also as to the best means of employing such lamps in their houses.

The recognition by the National Electric Lamp Association of the value of scientific study is exemplified by the fact that the Association has now installed and proposes to maintain at considerable cost, a special laboratory for the study of illumination from the joint standpoint of the ophthalmist and physicist. It is anticipated that much good work will be undertaken at this laboratory for the benefit of the general public and the lighting industry. This splendid example I would like to see imitated in this country.

Another striking example of co-operation between central station lamp manufacturer and consumer is afforded by the action of the Boston Edison Electric Illuminating Co., to whom belongs the honour of being the first supply company to organise an expert staff of illuminating engineers, from whose advice company and consumer alike could benefit.

During the three months that have elapsed since the inauguration of this department under the supervision of Dr. Louis Bell, the President of the Illuminating Engineering Society in the United States, no fewer than 450 applications for assistance have been received from customers, and advice was given free. It is also interesting to know that this number included no less than 19 churches.

We commend to the electric lighting industry of this country the far-seeing policy of our neighbours in the United States.

Another aspect of this question, which is causing some anxiety to those in a position to know, is the approach of a wholesale reduction in prices of lamps, coupled with the accompanying danger that a large number of cheap but inferior lamps may be put upon the market in this country (possibly the discarded examples of lamps used abroad), just as happened when the carbon filament lamp was first developed.

The Need for a Standard Specification.

We have now a standard specification by which the consumer may profit if he chooses to do so, while buying carbon filament lamps. Some experiments in this direction have been

made in Germany, having for their object the framing of a similar standard specification to be applied to metallic filament lamps, and I understand that attention is being devoted to the matter by the National Physical Laboratory in this country. In any case the time is coming when the desirability of such a standard will be very keenly felt. The great difficulty, however, in drafting a specification and in giving it practical effect lies in the fluctuation in the conditions to which the lamps may be subjected.

As explained above, we may mark on a lamp the conditions with which it ought to comply when properly treated; but, when it is placed on a circuit on which the voltage is only nominally and not actually that marked on the lamp, we naturally do not obtain the results that compliance with the specification is supposed to secure.

Arc Lamps.

In turning to the subject of arc lamps, I am again impressed by the extent of the material at my disposal, and the short time in which to make reference to the subject. Naturally, my remarks can only be very general, and I cannot enter into details of mechanism but only into general principles.

Two of the main factors of the old open carbon arc lamp on which attention has been concentrated, have been the luminous efficiency of the carbons and their life. We can, of course, always increase the efficiency of a carbon arc by reducing the diameter of the carbons, and so securing a higher temperature of incandescence. But by so doing we also increase their rate of burning away correspondingly.

In the ordinary carbon arc, as you are doubtless aware, the great majority of the light is thrown from a white hot incandescent spot of a positive carbon which we call the crater; the light from the arc itself, and even from the negative carbon, is relatively small. We have, therefore, to deal essentially with thermal radiation of an incandescent solid, and under these conditions the luminous efficiency is bound to be small because we produce a mere jumble of vibrations in which heat waves, which are useless from the luminous point of view, predominate.

Incandescent Vapours. — Recourse has, therefore, been had to a second possible way of increasing efficiency, namely, by the use of the principle of luminescence and the free, natural vibrations of a vapour instead of a solid. This was accomplished by introducing a suitable volatile chemical substance into the carbons.

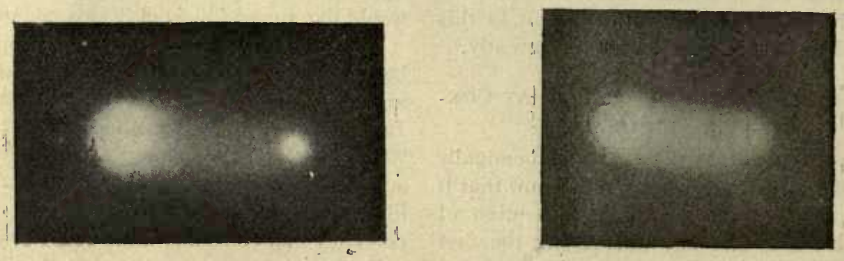
Flame Carbons.—Many attempts were made in this direction, both in the direction of impregnating the carbons with a solution, and in providing them with a suitable chemical core.

Under these conditions it was found to be possible to obtain a bridge of highly luminous vapour, from which the greater portion of a light is received. There were, however, many difficulties in the application of this principle. For instance, the early carbons were not sufficiently homogeneous and burnt with a flickering light. In addition the chemical materials tended to form a fusible non-conducting slag on the top of the carbons which interrupted the action of the arc.

This last difficulty was largely overcome by the introduction of inclined carbons.

Fig. 7, which represents some date given by Mr. Leonard Andrews in a paper before the Institution of Electrical Engineers three

Fig. 7.



Ordinary Arc. Flame Arc.

Illustrating the appearance of Arcs between Ordinary and Flame Carbons respectively.
(Andrews, Inst. of Elec. Engineers, 1906.)

years ago, makes clear the difference in the nature of the arc between pure carbon electrodes and the flame arc. In the latter case the vapour is a source of light, and in addition it is necessary to use a much longer arc of perhaps as large as three-quarters to one inch in length. Under these conditions we avoid the shadow from the negative carbon, characteristic of ordinary arc lamps, and thus save a considerable amount of light that would otherwise be wasted.

On the other hand, it has been pointed out that the distribution of light so secured is unfavourable for street lighting and, therefore, M. Blondel has recently brought out a patent type of carbons which enables a highly efficient white arc to be obtained between vertical electrodes. Carbons of this type are utilised in the Crompton-Blondel arc. (Fig. 8.)

The efficiency of a flame arc is far greater than that attained by the old type, reaching, under favourable conditions, as much as 0·2 watts per candle-power (M.S.C.P. naked arc). Some recent figures of Professor Morris on this subject are presented in the following table:—

EFFICIENCY OF VARIOUS TYPES OF CARBONS AND ARC LAMPS.

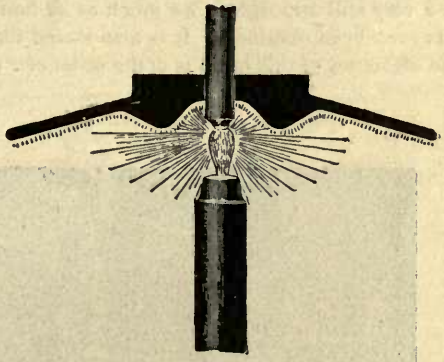
(Morris, *Illuminating Engineer*, Sept., 1908).

	M.S.C.P. per Watt
Carbons.	
High Grade Flame Carbons ..	2·9 to 3·3
Lower Grade ,, ,, ..	1·5 to 2·5
Ordinary Carbons Open	About 1
,, ,, Enclosed ..	About 0·6
Lamps.	
Lamp with High Grade Flame Carbons Enclosed	.. 3·9
Ditto Open	3·5 to 3·7
Lamp with Auer Carbons	.. 2·5
Lamp with Lower Grade Flame Carbons	1·4 to 2·5
Lamp with ordinary Carbons Open	About 1
,, ,, ,, Enclosed	About 0·75

Since the first commercial introduction of a successful flame by Bremer, many different types of flame lamps have been evolved. I can only make passing reference to a few of these, such as the Excello, Crompton-Blondel, Gilbert, Oliver, &c. The essential characteristic of all flame lamps is that the light is mainly, though not entirely, derived from luminescent vapour.

Efforts to Increase Burning-hours of Flame Carbons.—Even in the case of flame arcs, however, the gain in the efficiency was only secured with an accompanying increase in the rapidity of the wasting away of the carbons. Enormous candle-powers were obtained, but the first lamps produced only burnt for about six hours without re-carboning, and even so extremely long carbons had to be used, thus making the overall length of the lamp in conveniently large.

FIG. 8.



THE CROMPTON-BLONDEL ARC.

Oliver Magazine Lamp.—The design of flame carbons has got over this difficulty to some extent, but only partially. An ingenious method of meeting the difficulty was that adopted in magazine flame lamps, of which the Oliver lamp was an example. In this case a succession of carbons is stored within the lamp, and the wasted carbon being automatically replaced is thus used up. Evidently a lamp on this principle can burn for a considerable time without re-carboning. On the other hand, mechanism of this type is inclined to get out of order.

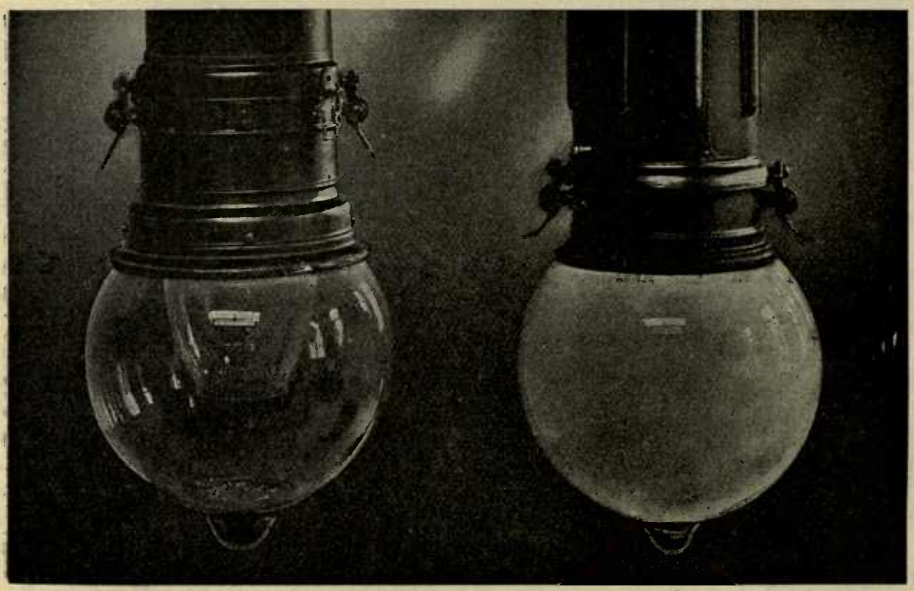
Enclosed Flame Arc Lamp.—It might naturally have been supposed that an attempt would be made to enclose flame lamps as had been done successfully in the case of the arc between pure carbons. In the United States in particular, where labour is dear, lamps of this type had had a great success. Unfortunately the deposition of fumes on the globe of the lamp and the quickly increasing opacity as a consequence, and also the fact that the efficiency of most flame carbons was considerably diminished when air was excluded, prevented this plan being feasible. Indeed, the condensation of fumes inside the globe has been found to be a defect in most flame arc lamps of the ordinary variety.

More recently, however, a modification has been made by the Union Electric Company in the Excello lamp, involving the in-

troduction of an inner globe, which causes the fumes to be carried away and condensed elsewhere; the same firm utilise a type of inner globe which, being prismatic, serves the purpose of modifying the natural curve of light distribution, so as to render it convenient for street lighting.

Two pairs of carbons burning consecutively are also used, and this is said to enable the lamps to burn for 34 hours without re-carboning; in a very still atmosphere as much as 42 hours has even been obtained. It is also stated that the efficiency of this lamp is of the order of 0·17 watts per M.H.C.P. In Fig. 9 will be seen the appearance of the globes of two identical lamps, one fitted with ordinary globe and the other with the new deposit free type, after 100 hours burning.

Fig. 9.



Excello Deposit-Free Globe.
Appearance of ordinary and deposit-free cover after 100 hours burning.

Very recently, too, Mr. Denman Jones has brought out a type of enclosed flame arc, by the aid of which the gases are completely removed and very long burning hours are secured. A general view of this lamp is shown in Fig. 10 (p. 19).

Lamps with Metallic Electrodes.—Another distinct direction in which the researches of arc lamps have progressed during recent years has been towards the complete replacing of carbons by metallic electrodes. Ladoff, Blondel, and others have done much work in this direction. The best known commercial type of lamp dependent on this principle, however, is the magnetite arc brought out by the General Electric Company in the United States.

This lamp utilises a negative electrode composed of a suitable mixture of magnetite and oxides of the rare metal titanium and other substances. A very long luminous arc is obtained, the quality of which, however, depends entirely on the constitution of the negative electrode. The positive electrode merely consists of a slab of copper. It has no influence on the quality of the light, nor does it waste away. The negative, however, wastes away at such a slow rate that the lamp, it is said, can be burnt 500 hours without re-carboning.

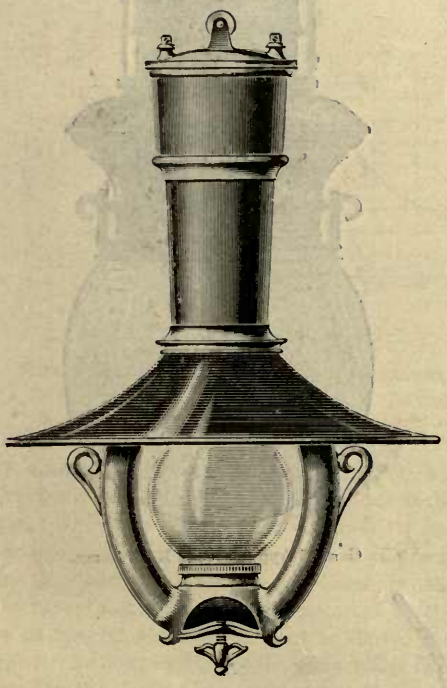
It is also said that the quality of the light, unlike that from most flame carbons, is extremely white; also that it is good for geographical purposes. (It is interesting to observe that the lamp has just been adopted for the street-lighting of Boston, as the result of exhaustive tests by the authorities in that city.) This, therefore, represents a departure in the direction of securing efficiency coupled with long life.

Miniature Arc Lamps. — Before leaving the subject of arc lamps, reference may.

perhaps, be made to one other interesting development in arc lighting, namely, the introduction of miniature enclosed arc lamps taking a small current of perhaps 1-2 ampères only. It was long felt that there was a need of some source having a candle-power intermediate between that of the carbon filament and the arc lamp.

The introduction of flame carbons only resulted in the production of lights of more enormous candle-power than ever, while it was found difficult to make carbon filament glow

FIG. 10.



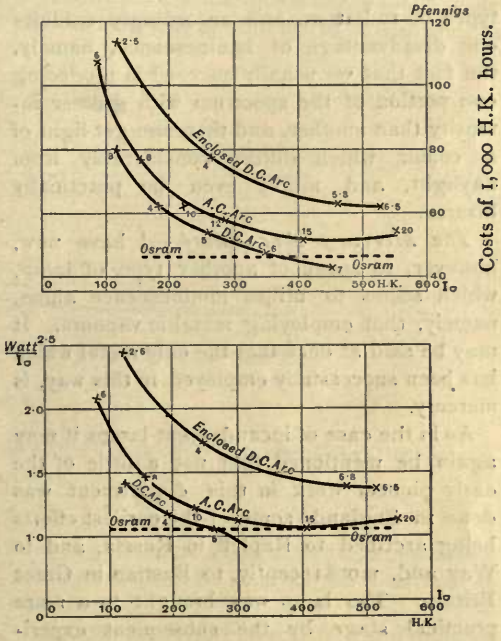
THE JANDUS REGENERATIVE ENCLOSED FLAME ARC LAMP.

lamps of high candle-power. The Nernst lamp, it is true, did something to fill the gap, but its complexity was a disadvantage. Shortly afterwards there arose a rapid succession of small enclosed arc lamps of this kind called by various names, the Miniature, Mignon, Rignon, Baby, Lilliput, &c.

The Regina Arc Lamp.—The Regina Arc Lamp Company claim to have achieved an improvement in their Regina, Helia, and Reginula enclosed lamps by securing a more complete exclusion of the air than had been previously found possible, coupled with a reduction in the diameter of the carbons used. It is claimed, for instance, that the Regina lamp consumes only 0·8 watts per M.H.S.C.P., and will last for 250 hours without re-carboning.

A consumption of only 0·3 watts per M.H.S.C.P. therefore can be obtained if one is content with a burning period of only 15 to 20 hours. An example of the extremely simple character of the mechanism of these lamps is

FIG. 11.



COMPARISON OF ENCLOSED ARC LAMPS AND HIGH CANDLE-POWER OSRAM LAMPS. (H. Remané, Verband Deutscher Elektrotechniker, 1908.)

The numbers attached to the points on the curve represent the current in Ampères taken by the various Arc Lamps.

kindly exhibited by Messrs. Marples, Leach and Co., to-night.

Comparison of Small Arc Lamps and High Candle-power Tungsten Lamps.—More recently still, however, a change in the situation has been brought about by the introduction of high candle-power Tungsten lamps, which rival the most efficient enclosed arc in efficiency and are without the disadvantage of requiring occasional attention. The relative merits of both types of lamps have been recently treated by H. Remané (E. T. Z., Aug. 20th;

1908), some of whose results are exhibited in Fig. 11.

Vapour Lamps.

Introduction.—It will be remembered that at the beginning of this lecture referred to the existence of two distinct methods of generating light—by incandescent solids and by luminous gases; I have also mentioned how we may expect to secure more efficient results by the utilisation of radiation of the latter variety.

A flame lamp, as we have seen, utilises both types of radiation, and accordingly exhibits one disadvantage of luminescence, namely, the fact that we usually succeed in producing one portion of the spectrum with greater intensity than another, and therefore get light of a colour which differs considerably from daylight, and might even be practically bizarre.

The Mercury Arc Lamp.—I have now, however, to speak of another type of lamp, which seems to utilise luminescence alone, namely, that employing metallic vapours. It may be said at once that the only metal which has been successfully employed in this way, is mercury.

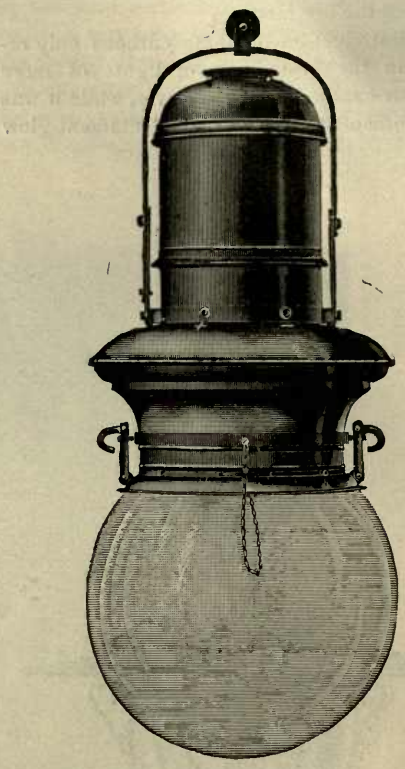
As in the case of incandescent lamps it may again be mentioned that not a little of the early pioneer work in this department was done in England, some of the earliest efforts being ascribed to Rapieff in Russia, and to Way and, more recently, to Bastian in Great Britain. The lamp was brought to a more practical stage by the subsequent experiments of Arons in Germany, and Cooper-Hewitt in the United States. Both of these investigators utilised a long tube containing mercury vapour, which is essentially the same as that used in the mercury vapour lamps of to-day.

There have, however, been a number of very ingenious inventions regarding the regulating mechanism of these lamps, into which I cannot enter in detail. A few of the most recent types of lamps of this kind are shown here by the kindness of the Westinghouse Company to-night.

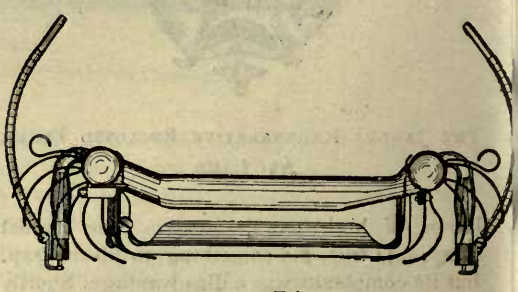
The chief point of interest in the most recent type introduced by this firm is the introduction of a new automatic system of starting the lamp without "tipping," the arc being started by the impression of instantaneous high P.D. across its terminals.

The efficiency of these lamps is difficult to determine, because of the peculiar character of the light, and also because the extended nature of the source makes accurate photometry very difficult. It has, however, been stated that a consumption as low as 0·6 watts per candle-power has been obtained, and this was long thought to be the limit, since both an increase and a decrease in the pressure of the mercury vapour in the tube proved to lead to a fall in the efficiency.

Fig. 12.



General Appearance of Küch Lamp.



Small Quartz Tube.

The Küch Lamp. A Mercury Vapour Lamp utilising a small tube composed of special quartz glass.

The great length of tube (those of 110 volt lamps are nearly 1 metre in length and 3 to 4 centimetres in diameter), though promoting diffusion of light, is a disadvantage in some respects.

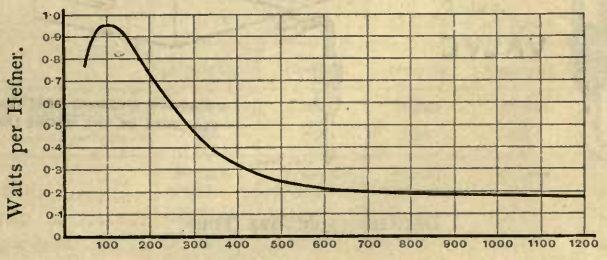
The greatest disadvantage under which these lamps labour, however, is the peculiar colour of the light. A line spectrum pure and simple is obtained, the greater bulk of the radiation being concentrated in three lines into yellow, green, and blue respectively, and the red element being almost entirely absent. This line spectrum is, of course, characteristic of luminescence.

Dr. Küch, however, constructed a tube of very refractory special quartz glass which would stand a much higher temperature than ordinary glass; it was then found that the efficiency increased as the power given to the lamp was increased, in accordance with the curve shown in Fig. 13.

It will be seen that the consumption per candle-power, after rising to a maximum, begins to fall again, until eventually a value of about 0·27 watts per M.S.C.P. is attained.

The quartz 110 volt tube is only about 8 centimetres long and 1½ centimetres in diameter. I

FIG. 13.



CURVE ILLUSTRATING EFFECT ON EFFICIENCY OF KÜCH LAMP OF INCREASING WATTAGE AND TEMPERATURE.

I cannot dwell upon all the attempts that have been made to improve the colour of the light. They are many. For instance, it has been proposed to mix lithium salts in the mercury in order to provide red lines in the spectrum; also to modify the spectrum by the use of special electrodes; also to derive red light by the degradation of the ultra-violet rays given by the lamp by means of fluorescence. None of these methods appears yet to have crystallised into anything very practical.

The Küch Quartz-Tube Lamp.—Recently, however, an interesting advance has been made in Germany by Dr. Küch. (Paper read before the Verband Deutscher Elektrotechniker 1907.) Hitherto, if the pressure within the lamp was increased beyond a certain point, the increase in temperature caused glass of an ordinary variety to melt, and therefore brought the lamp to a premature end.

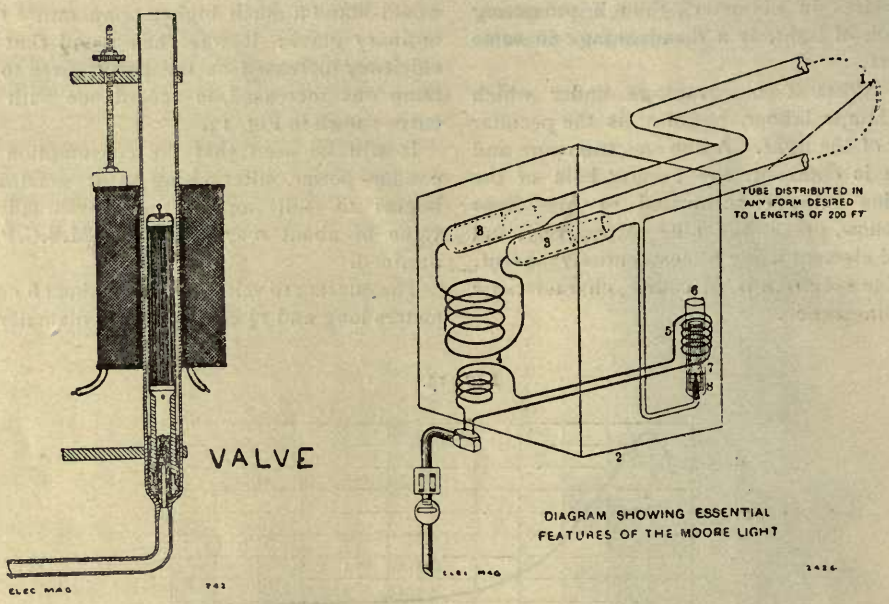
Quartz-Tube lamps, intended mainly for the production of ultra-violet light, and not for ordinary purposes of illumination, had previously been introduced by Heraeus, in Hanover, Germany.

may say that the glass of this tube represents a very considerable item in the total cost of the lamp.

Another interesting characteristic of the lamp is the fact that at the high temperature and pressure existing within the lamp luminescence is partially replaced by ordinary incandescence, and the line spectrum broadens out into a more or less continuous one, with the result that the colour of the light is distinctly improved, and contains a certain amount of red rays.

Another striking peculiarity of the lamp arises from the fact that quartz glass allows ultra-violet light to pass through, whereas glass of the ordinary variety is gradually decomposed by it, or degrades it into heat-energy. As a result the quartz-tube lamp has a very powerful action on the skin and eyes, and is also believed to possess special uses for the destruction of bacteria, the sterilisation of water, &c. For ordinary purposes of illumination it is necessary to screen the quartz tube with an absorbing glass envelope, which transmits the visible radiation, but largely absorbs the ultra-violet light.

FIG. 14.



DETAILS OF MOORE TUBE.

FIG. 15.

MOORE TUBE INSTALLATION LATELY IN USE IN THE COURTYARD OF THE SAVOY HOTEL, LONDON.

It has been mentioned that lamps of a similar character have been devised in Germany for purely photographic purposes, some of them, such as the Heraeus lamp, employing quartz glass ; others, like the Uviol lamp, utilise an envelope composed of a newly-discovered glass, which transmits ultra-violet energy.

The Moore Tube. — And now I have to mention a very interesting type of an illuminant recently brought out in the United States by Mr. D. Macfarlane Moore (Am. Inst. of Elec. Engineers, 1906).

It has, of course, long been known that gases can be made luminous when subjected to an electrical discharge in a highly rarified condition. The ordinary Geissler and vacuum tubes are illustrations of this principle. To Tesla and others had occurred the idea of utilising this effect in order to secure an efficient illuminant. It was, however, found that the condition of the gases within the tube quickly changed, partly owing to the absorption of gas by the electrodes, and means had, therefore, to be adopted to control automatically the conditions of the gaseous contents of the tube. These devices, however, were for long unreliable.

To Mr. Moore belongs the credit of having very carefully studied the conditions and qualities of gases most favourable to the production of light, and the invention of an extremely ingenious form of valve by the aid of which the pressure of the gas within the tube was maintained exactly constant. The essential details of this valve and the lamp in general are shown in Fig. 14. During my recent visit to the United States I had the privilege of seeing these lamps in action.

The illuminant consists of a long tube, which may be 30 ft. or 40 ft. in length, filled with suitable gases at a very low pressure and subjected to an electrical high tension discharge from a small electrical transformer. If a house

TABLE II.

COST OF GAS AND ELECTRIC LAMPS.

(Assuming Gas Costs 0·2 Fr. per cubic metre, Electricity 0·7 Fr. per KW. hours.)

	Incandescent Gas.		Incandescent electric lamps.			
			Carbon. 32 C.P. for 300 hours.		Tungsten. 32 C.P. for 1000 hours.	
	Upright.	Inverted.	110 volt.	220 volt.	110 volt.	220 volt.
Hourly consumption in watt-hours or litres	Litres. 80	Litres. 80	Watts. 100	Watts. 100	Watts. 35	Watts. 45
Corresponding cost in francs	Francs. 0·016	Francs. 0·016	Francs. 0·07	Francs. 0·084	Francs. 0·0245	Francs. 0·0315
Cost of renewals per hour	0·0025	0·004	0·0017	0·003	0·0037	0·0062
Total cost of lighting per hour	0·0185	0·020	0·072	0·087	0·028	0·038
Mean Sph. C.P.	55	50	28	28	28	28
Cost per Mean Sph. C.P. per hour	0·00032	0·00040	0·00258	0·031	0·010	0·0136
Assuming cost of gas 0·10 Fr. per cubic metre, electricity 0·10 Fr. per KW. hours.						
Cost of gas consumed	0·008	0·008	0·01	0·011	0·0035	0·0045
Total cost, including renewals	0·0105	0·012	0·012	0·014	0·0072	0·0107
Cost per Mean Sph. C.P. per hour	0·00019	0·00024	0·00043	0·0005	0·00026	0·00038

Formula enabling one to calculate running costs of electric lamps:

$$C = \frac{p}{TL_0} + \frac{p'W}{1000}$$

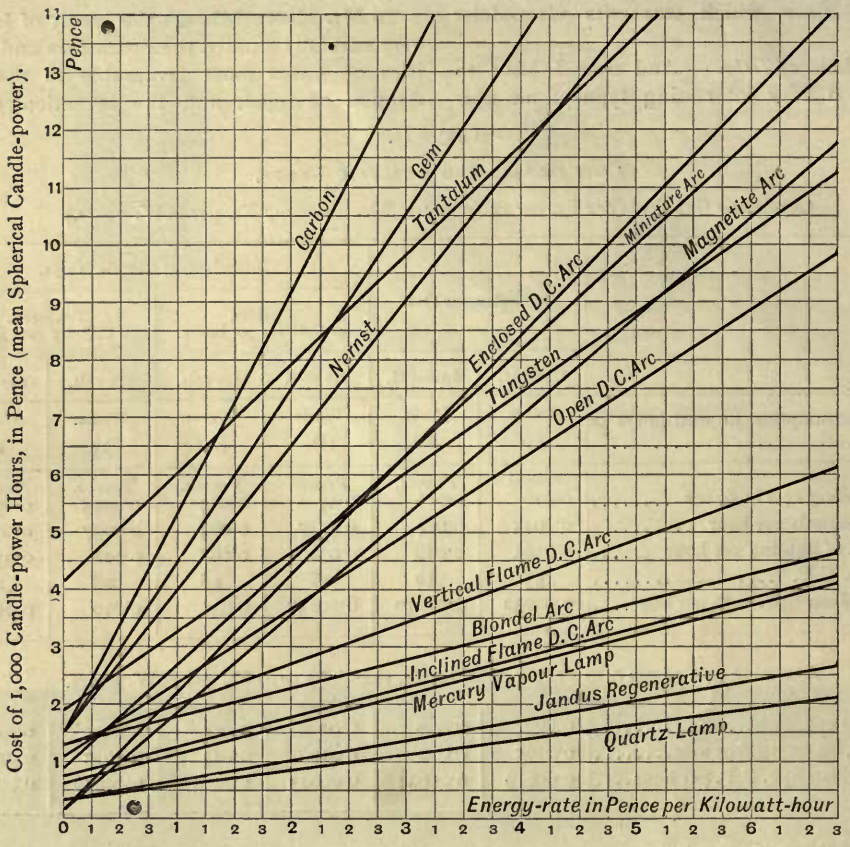
where p = Cost of lamp. L_0 = Mean Sph. C.P.
p' = Cost per KW. of electrical energy. T = Life before lamp is discarded.
W = Watt per Mean Sph. C.P.

(M. Blondel, Congrès de Marseille, 1908.)

is lighted by this system the tube is supposed to ramify round the rooms up the staircase, &c., and, in fact, entirely to replace the ordinary wiring.

installation put up in this country. This was described by Dr. Fleming in an early part of the *Illuminating Engineer* (Vol. I., Jan., 1908, p. 19), and he states that a con-

FIG. 16.



COMPARATIVE COST OF THE VARIOUS ILLUMINANTS. A. A. WOHLAUER. *The Electrical World* (N.Y.).

The cost of renewal and maintenance is taken as $\frac{P \times 1000}{l \times L_s}$, where L_s means the mean spherical candle-power.

l, life of *lamp* in the case of incandescent lamps; *glower* in the case of Nernst lamps; *electrode* in the case of arc lamps; *vapour-tube* in the case of vapour-tube lamps.

P, price of *bulb* in the case of incandescent lamps; *renewal of glower and ballast* in the case of Nernst lamps; renewal of *electrodes* and *trimming* for arc lamps; *tube* for vapour lamps.

The consumption per candle-power of the tube varies according to the nature of the gas used; so does the colour of the light. Thus a tube filled with nitrogen yields light of a yellowish, pinkish colour. But by using carbon-dioxide Mr. Moore claims to obtain a beautifully white light which resembles daylight more closely than any other known illuminant.

Fig. 15 represents the Moore tube installation recently in use in the courtyard of the Savoy Hotel. This is, I believe, the only

sumption of 1·78 watts per candle-power was obtained. The advocates of the system, however, contend that this does not truly represent the value of the light because its diffuseness and low intrinsic brilliancy enable one to secure better results, as far as the eye is concerned, than photometrical experiments would suggest.

The Relative Costs of Different Illuminants.—Having described so many electrical illuminants I may, perhaps, be expected to

give some idea of their relative costs as compared with gas lighting, &c. I may explain that I myself only regard Tables of this kind as of very general interest, because the actual decision in any practical case depends very largely upon the local conditions. This is brought out by a Table containing some results of Monsieur Blondel in a paper to which I have previously referred.

You will also see that the relative costs of gas and of electricity can vary very greatly, even when lamps of the same type are considered.

Fig. 16 connects the cost of various electrical illuminants with various costs of electrical energy as given by Wohlauer. (See *Illuminating Engineer*, Vol. I., p. 663.)

Other Methods of Generating Light—Phosphorescence and Fluorescence.

There remains one conceivable method of generating lighting which many of you may consider fanciful, but which, nevertheless, seems to me to possess great scientific possibilities, and, indeed, has been carried to wonderful perfection for certain purposes by Mr. Hammer in the United States and others. I allude to the phenomena of phosphorescence and fluorescence.

I may explain the distinction between the terms "phosphorescence" and "fluorescence" that I have just used. By the latter we usually understand the degradation of ultra-violet into visible light energy which takes place only while the stimulus is applied.

Phosphorescence, on the other hand, is usually taken to indicate an effect of this kind which continues after the stimulus is removed, so that we may excite a phosphorescent substance, and subsequently use the light that continues to be emitted.

Mr. A. C. Cossor has kindly arranged for the exhibition of a few experiments illustrating these phenomena. Here, for instance, are some specimens of Willemite, which fluoresce under the rays of the Uviol tube. A still more interesting example of induced fluorescence is the effect of only 5 milligrams of radium in exciting quite a large piece of this substance. Now that the lights are turned down you will observe a distinct green luminous appearance of the Willemite, which appears as the radium is brought near, and disappears again as it is withdrawn.

It has been proposed to modify the spectrum of the quartz mercury lamp by painting the tube with fluorescent substances.

Professor S. P. Langley, who studied the nature of the phosphorescent light from a firefly, characterised it as the most efficient illuminant in existence, and the researches of Nichols and others suggest that for some reason or other phosphorescent materials almost invariably contain the greater part of their radiation within the visible spectrum. It may be that these researches will lead to new methods of illumination in the future.

Lecture II.—Delivered February 22, 1909.

GAS-LIGHTING.

Introduction.

In dealing with the programme of my lecture on gas, I find myself again confronted with a subject which is extremely vast, and to many aspects of which separate and exhaustive Cantor lectures have been devoted by my predecessors.

For instance, Professor Vivian Lewes alone has dwelt on the practical aspects of gas lighting, the theory of the incandescent mantle, and other allied subjects, at great length, and I should like to refer those of you who wish to receive fuller details on these points, to the original lectures.

I may, however, make clear at the very beginning of this lecture, that I propose to restrict myself entirely to gas lighting proper, and not to deal with generating problems and distribution, except in so far as they are immediately connected with illumination. I shall not, therefore, trouble you with an exhaustive description of the processes by which gas is produced, nor with particulars of the composition of ordinary town gas, water gas, producer gas, or any of the other varieties of gas that have played a more or less direct part in gas lighting.

Historical.

It may, however, be interesting to give a few particulars of the early development of gas lighting in Great Britain and other countries, and in this connection I should like to refer you to an interesting article by Dr. R. Böhm (*Illuminating Engineer*, February, 1908), and also to some remarks on this subject in Mr. W. H. Y. Webber's book on "Town" gas.

One of the very earliest records of the manufacture and storage of illuminating gas, is that in the Transactions of the Royal Society for 1739, when the experiments of the Rev. Dr. John Clayton on this subject were communicated.

Dr. Dundonald, it is also known, carried out some experiments on the subject in 1787, but William Murdoch, who took up the subject a few years later, and who lighted his factory in Redruth in 1792, and his factory at Soho, Birmingham, in 1802, is regarded as in many respects the father of the industry. Subsequently the Chartered Company was formed in London in 1810, by Winzler, a Moravian, who had become interested in the subject, and travelled to London to give his ideas practical shape, and in 1813, Westminster Bridge was lighted by gas for the first time.

A name which, like that of Murdoch, will always be inseparably connected with the early beginning of the gas industry in this country, is that of Mr. Samuel Clegg, a pupil of his, who afterwards carried out his work, in connection with the Chartered Company, with indomitable perseverance and ingenuity.

England can, therefore, claim to have done much of the early pioneering work in gas lighting, though similar work had been done in Paris, by Lebon, in 1784, and in Germany even earlier; it was not, however, until the 19th September, 1827, that the famous street of Unter den Linden, in Berlin, was lighted by gas.

It has often been said that nothing was so stimulating to the development of gas as the rise of electricity. On the other hand, electrical engineers (who have certainly had sufficiently great initial difficulties of their own to overcome) ought to remember with gratitude the work of the gas companies in overcoming early prejudices, and paving the way for their future efforts. At the time when the Chartered Gas Company was formed, the idea of an illuminant transmitted to a distance was one that the general public found it impossible to conceive, and Clegg, in his early efforts, was hampered by an incredible degree of misunderstanding as to what lighting by gas really consisted of. In addition, he had to face the difficulties of securing materials, and to devise means of overcoming unexpected obstacles.

For instance, Clegg is said to have been at one time unable to obtain the necessary metal piping, and to have had recourse to strings of old musket barrels screwed together.

For a time, there was no means of measuring the gas supplied; consumers hired their lights at a yearly rental, and there was much misunderstanding and dissatisfaction. The

early difficulties of gas in London were accentuated by the existence of several competing companies, who apparently were not above exceedingly unscrupulous tactics in competing with one another. Mr. Webber, for instance, relates how one company would occasionally instal a show lamp, free of charge, in order to attract a consumer, and were not above attaching it to the mains of a rival.

Actions like these led to a species of guerilla warfare between the competing companies. Gangs of navvies were employed for offensive and protective purposes, and the streets were in an almost continuous state of upheaval owing to their exertions. Eventually, however, an amalgamation of these various companies was effected, and the supply of gas began to resemble more closely the conditions of the present day.

Early Type of Burners.

The earliest method of burning gas was, of course, by the use of the so-called flat flame burners, which we should now consider extremely inefficient, for they yielded only about two to three candle-power per cubic foot of gas, even under the most favourable conditions. Of course, however, it must be remembered that gas, unlike electricity, may vary in quality in each district. For instance, the Act of 1860 prescribed that the town gas burned under certain specified conditions in a standard Argand burner should give 15 candle-power; but the rich local cannel coal in Scotland was capable of yielding as much as 20 or even more candle-power.

Similar results could, of course, be obtained by enriching the gas by the addition of some volatile hydrocarbon. For instance, in the "albo-carbon" burner, the gas must pass over naphthalene, which presently became volatile in the heat of the flame, and mixing with the gas emerging from the burner considerably improved its quality. It was, however, but a cumbrous device.

Somewhat better results than those mentioned above could also be obtained from the Argand burner, but this again occasioned a more delicate and unsteady flame. Yet another early improvement was in the direction of the so-called regenerative lamps, in which the gas was heated by the flame before it passed into the burner, and a greater flame temperature and improved candle-power were obtained as a consequence. The Wenham lamp depended on this principle.

Table of Efficiencies of Various Burners.

(W. Grafton, Practical Gasfitting.)

Type of Burner.	Specific Consumption. (Candle power per cubic foot of gas per hour.)
Flat-flame, Batswing..	4–6·1 (with 30 candle gas)
Ordinary Argand	2 : 7–2·9 (with 16 candle gas)
Standard Argand	3 : 2–3·35 (with 16 candle gas)
Albo-Carbon light	5–6
Regenerative lamps ..	10–12
Acetylene	generally 35, best conditions 48.
Welsbach "C" 1893 burners	12–14
Welsbach "C" 1898 burners.....	19–23·4
Welsbach "C" Bansept	18–20
Added:—	
High-pressure incandescent	40–50
Keith high-pressure Light	60–70

The Coming of the Incandescent Mantle.

It was, however, not until the introduction of the incandescent mantle and the Bunsen burner that any really great progress seemed possible.

I need not enter in any detail into the wonderful researches of Auer von Welsbach. The lectures of Prof. Vivian Lewes before this Society have given us an insight into the theory of the mantle, as far as it was known at the time of these lectures.

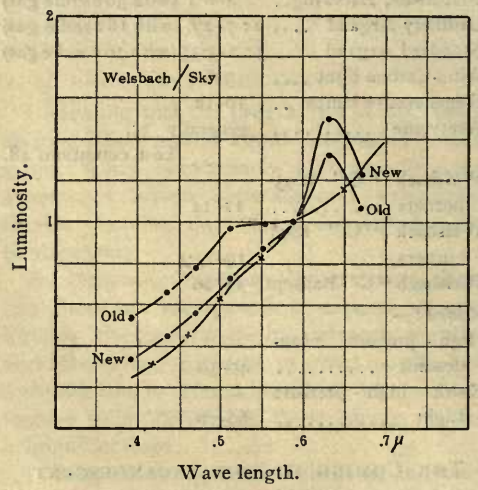
Another instructive paper dealing with the theory of the radiation of the mantle in some detail, was that of Professor Rubens, before the British Association, a few years ago.

It has been suggested that the effect is due to pure thermal incandescence, and that the temperature of the mantle is far hotter than that of the Bunsen flame. Again, it has been supposed that catalytic action takes place among the oxides which are present in the mantle. It is also known that the rare earths are peculiarly capable of showing luminescence, and that only when small impurities are present does this luminescence take place, and lastly, it has been pointed out that the Bunsen flame is rich in the ultra-violet rays that are supposed to call this luminescence into play. Yet it does not appear that we have arrived at a complete understanding regarding the action of the mantle at the present day.

Colour of Light from Mantles.—Even after this discovery, however, the mantle was far from perfect. Its luminosity deteriorated

very quickly, and the quality of the light was of an unpleasant greenish colour. To-day these drawbacks have been very largely removed. The following figure for instance,

FIG. 17.



SHOWING SELECTIVE RADIATION AND PECULIAR COLOUR OF OLD TYPES AND MANTLES.

(Nichols, Trans. Illum. Eng. Soc. New York, May, 1908.)

shows the results of Nichols, for mantles of the present day compared with old-fashioned ones as regards the colour of the light produced. It will be seen that the more old-fashioned mantles yielded a spectrum showing considerable selective radiation, and a corresponding deviation from daylight, which is much improved in the later varieties.

Durability of Mantles.—Other incidental difficulties have been the tendency of mantles to burn into such a shape as not to be completely encircled by the flame.

In this connection, it is somewhat interesting to observe a recent device consisting of an infusible conical core, which is placed over the crutch of an incandescent mantle, and is said to guide the flame on to the mantle itself, and to result in an improvement of 20 per cent. in efficiency. [Since writing the above, I observe that Mr. A. Forshaw, in a paper read at the annual meeting of the Gas Institute this year, describes some experiences of cores of this kind, which are also satisfactory.]

After referring to the other qualities of mantles of importance, perhaps I may be expected to give some details of life tests. I may, therefore, refer to some tests undertaken about two years ago by Böhm (*Das Gasgluhlicht*, 1905), according to which you will see that relatively efficient results could apparently even then be obtained for 300 to 600 hours of life. (Fig. 18.)

As in the case of electric glow lamps, however, one feels that practical conditions are widely different from those prevailing in laboratory tests. Makers of lamps in England, at the present day, feel that one of their chief needs is a really good mantle, those in even ordinary burners requiring renewal on the average every 200 hours. There are so many respects in which a laboratory test is exceptionally favourable to the performances of mantles. For instance, reference need hardly be made to the effect of even a slight vibration; this, it is true, has been reduced by the many ingenious anti-vibration devices which Mr. George Helps, of Nuneaton, Messrs. Parkinson and Cowan, and others, have devised. In addition, as Mr. Wild has recently shown (*Journal of Gas Lighting*, April 2nd, 1907; *Illuminating Engineer*, 1908, p. 783) the results from any mantle depend very greatly on such factors as the pressure and quality of gas available, the type of chimney used, and the adjustment of the proportions of gas and air. The variations in these conditions really make it essential for a gasfitter to adjust each burner to suit the local requirements. (Fig. 19, p. 30.)

In addition, I need hardly say that the occasional blowing out of accumulated dust in the burner, is necessary. In public lighting, too, even the best lamps are not always unaffected by gales of wind, which have a very important influence on the question of renewal. Altogether it is highly probable that the termination of life of a mantle is usually determined by breakage, rather than diminution of candle-power, just as is not infrequently found to be the case for metallic filament lamps. Probably too, as in this case, variations in pressure are not without influence. It has even been suggested that a governor ought to be installed at the meter of each and every consumer.

New Types of Mantles.—Besides the other improvements referred to in mantles, notable advances in their durability have lately been achieved. The introduction of the Ramie mantle about 1898 was regarded as a great advance.

Two years ago a new departure in incandescent lighting was introduced by the Plaissetty Company in the form of the Monarch soft or non-incinerated mantle. The advantages of a soft mantle for convenience in packing and immunity in handling and transit are obvious. The greatest danger to inverted in-

cinerated mantles, namely, the risk of fracture at the ring in packing, is claimed to be avoided. But the greatest advantage offered by the soft mantle, it is said, is the latitude which it gives in burner development. By the use of a non-incinerated fabric, shapes and sizes can be obtained, which are practically impossible in an incinerated form.

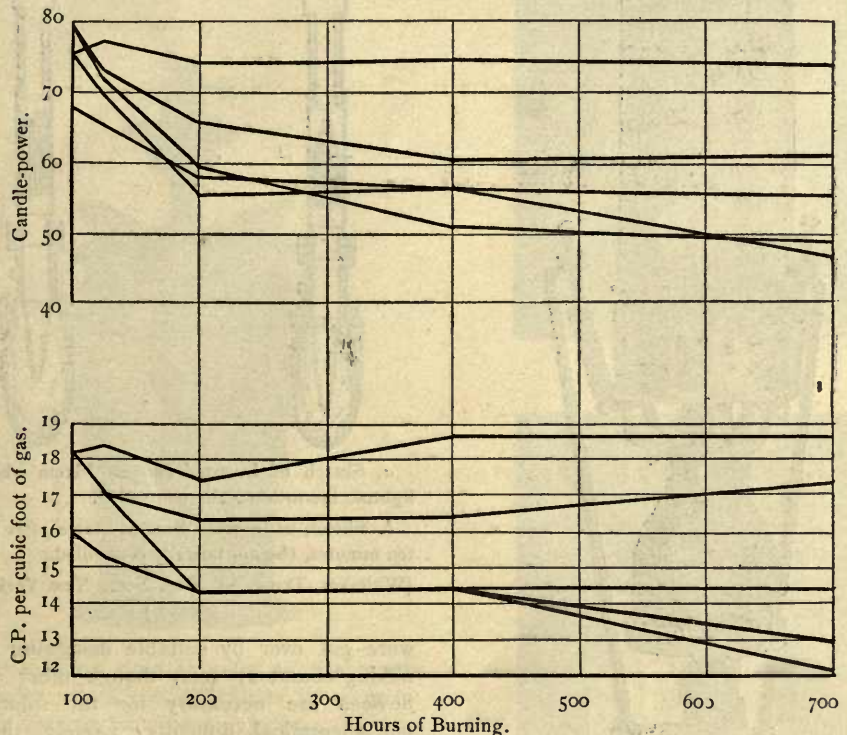
For a soft mantle certain conditions must be satisfied :—

1. The illuminating salts should be compact and in oxide form.

Next I may mention an interesting new development, namely, the Hella Bushlight, which, as you will see by the example kindly supplied here to-day, consists not of a mantle but of a bundle of rods composed of suitable rare earths. (See Patents Nos. 3785 and 9622 of 1908.)

The great claim made for this system is, that, while yielding an efficiency approaching that of ordinary mantles, the illuminating apparatus itself is exceptionally durable.

FIG. 18.



LIFE-CURVES OF INCANDESCENT MANTLES (Böhm).

2. The fabric should contain the minimum of cellulose.

3. The fabric should be shaped and the cellulose easily burnt out.

Another type of artificial silk mantle recently brought out, that of the Cerofirm Company, is stated by Böhm (*Illum. Eng.*, June, 1909), to be a great advance, having like the Plaisetty mantles, good elastic properties, together with improved efficiency and a whiter quality of light than was obtained previously. This is said to be due largely to the special nature of the impregnating salts used, which, after burning off, leave a very fine and durable surface of oxide behind.

DEVELOPMENT OF THE BUNSEN BURNER.

I may now make some reference to the development of the Bunsen burner, the other important factor in the incandescent light.

The efficiency yielded by an incandescent mantle depends to a very large extent on the flame temperature obtainable, and the possibility of securing perfect combustion of the gas supplied. The original Bunsen burner only consumed about one part of gas to two of air, whereas the average kind of town gas requires about $5\frac{1}{2}$ to one for complete combustion. By suitably designing the burner we can make a mixture of about one of gas to three of air, but any attempt to produce a poorer mixture than

this causes the flame to light back, if special provision is not made to avoid it. The device introduced into the ordinary incandescent burner to avoid this possibility merely consisted of a wire gauze acting on the principle of the Davy safety lamp.

Other details in the burner have been devised for the purpose of securing an intimate mixture of gas and air. For instance,

FIG. 19.

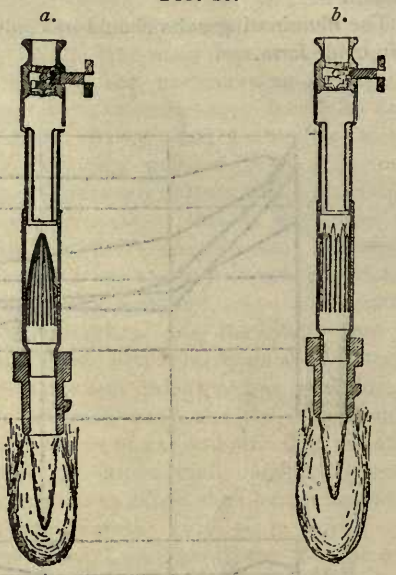
TYPE OF ANTI-VIBRATION HOLDER. (Messrs. Parkinson and Cowan.)

in the Welsbach-Kern burner, a tapering cylinder is added to the burner in order to give the gas and air opportunity of mixing completely, and a peculiar twisted head is fitted with the object of producing a swirling motion of the mixture as it appears at the nipple and is burned.

INVERTED BURNERS.

Within the last few years a very great advance has been effected by the introduction of inverted burners. The early experiences of this burner were not entirely satisfactory, and there were many initial difficulties to overcome—so much so that even in 1906 there were many who doubted whether the burner would ever become a commercial success. For instance, the tendency to light back appeared to be accentuated, there was a tendency to produce a hissing noise, and the conduction of heat upwards to the fitting caused it to wear out very rapidly. Most of these difficulties

FIG. 20.



a. Sketch of Inverted Bunsen Flame when first lighted, thermostatically controlled.

b. Sketch of Inverted Bunsen Flame after burning ten minutes, thermostatically controlled.

(Whitaker, Trans. Ill. Eng. Soc., New York, Dec., 1907.)

were got over by suitable designing of the mixing-chamber, &c., though other special devices are necessary for the solution of one theoretical difficulty, namely, the fact that the burner, after burning say ten minutes, becomes so much hotter as a whole than it was originally, as to call for slight adjustment of proportions of gas and air in order to obtain the most perfect results.

A very ingenious method of controlling the proportions of gas and air, and of getting over this difficulty has been described by Litle and Whittaker (Trans-Illuminating Eng. Soc., New York, 1907); it involves a special thermopile-controlled valve, by means of which the proportions of gas and air necessary for complete combustion are automatically regulated. (Fig. 20.)

In passing it is interesting to note that Clegg, very early in the history of gas lighting, devised a self-closing burner with thermostatic

action for the purpose of shutting off the gas whenever the flame became accidentally extinguished in order to satisfy the fire insurance authorities (Webber, "Town Gas and its Uses," page 28).

The inverted incandescent mantle, however, is of course to-day an accepted fact, and possesses very distinct merits. For instance, apart from improved efficiency, the attachment of the mantle by means of its entire rim is distinctly preferable to the system characteristic of the upright burner of merely hanging the mantle on a crutch.

FIG. 21.

I cannot find time to refer to the many devices by which the difficulties inherent in inverted burners have been overcome. A few examples of such devices are exhibited here to-night. For instance, the Hands cooled burner is provided with deflecting wings which conduct the heat away and prevent discolouration of the fitting. The principal advantage claimed for this burner is that its winged deflections serve the purpose of preventing discolouration of fittings, and keep the head of the burner cool. In addition, the air and gas adjustment is claimed to be exceptionally easy, the head always remaining perfectly cool after it has been burning for hours.

A test, I am informed, has recently been made by one of the largest gas companies in this country, according to which a burner was fitted on a polished brass adapter and was left burning from 7 a.m. until 10 p.m. for a period of six weeks. At the end of that time the finish of the adapter was found to be not discoloured or injured in any way whatever. (Figs. 22, 23.)

In the Bland burners, again, a patent anti-lighting-back arrangement is provided,

FIG. 22.

FIG. 23.

TYPES OF BLAND INVERTED BURNERS.

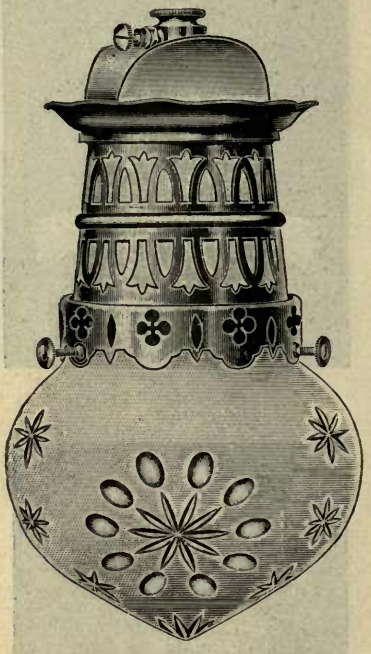
and there is also a special carrier to grip and support the mantle, which is not attached to the actual burner, with, it is claimed, the result that the life of the mantle is prolonged, because the shocks occasionally administered to the burner are not communicated to the mantle directly.

Other modern types of inverted burners on exhibition are the Omar and Mascot types of Messrs. Moffats, Limited. One essential de-

tail of these burners is the use of a perforated outer metal casing with which the products of combustion are not allowed to come in contact owing to the use of an opal glass collar. In this way it is claimed the burner retains its original appearance for months without becoming visibly discoloured or tarnished.

In the Mascot burner, in addition, the air is slightly warmed before reaching the mixing chamber, some of the waste heat of the burner being utilised for this end. This serves the

FIG. 24.



OMAR INVERTED BURNER. (Moffat.)

double purpose of producing a good velocity of the gas and air mixture and favourable conditions of combustion, and at the same time of cooling the parts of the burner over which the mixture passes and preventing consequent discolouration.

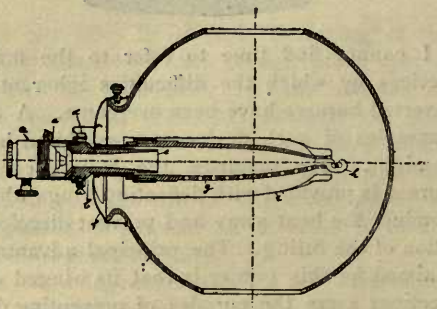
In addition, inverted mantles have a smaller and more compact form, and seem not to deteriorate and split so readily. The advantage on which most stress has been laid, however, lies in the improved distribution of light, the maximum candle-power being usually obtained in a downward direction. The exact nature of the distribution curve depends to some extent on the shape of the burner. They may be longer than they are broad, and it is then possible to obtain a good downward component, and yet at the same time stronger intensity at a downward angle; this, of course, is the nature of curve we mainly desire for street lighting, and inverted mantles, as will be mentioned later, have recently been applied for this purpose, with success in Berlin, and more recently still in Fleet-street, London.

FIG. 25.

MASCOT INVERTED BURNER. (Moffat.)

It may be new to some of you to learn that a firm in Berlin manufacture a type of burner with a mantle in a horizontal position (Czudnochowski, *Illuminating Engineer*, Vol. 1., 1908, p. 582). It is called the

FIG. 26.



"TUBUS" HORIZONTAL BURNER.

Tubus burner, and is claimed to be specially suitable for the illumination of shop windows, where a strong downward component is desired. (Figs. 26, 27.)

HIGH-PRESSURE GAS-LIGHTING.

I now come to one method of improving the efficiency of incandescent gas lighting, which,

Fig. 27.

"Tubus" Burners as arranged for Shop Lighting.

perhaps more than any other, has led to immense developments in recent years, namely, the use of high-pressure gas. There is no inherent advantage in using high-pressure gas except for the purpose of producing a more intimate mixture of gas and air coupled with a greater velocity of gas issuing from the burner, and therefore increased flame temperature with more perfect combustion.

Time will not allow me to enter into details as regards the many different systems of compressing the gas for subsequent use in this way, but I may make mention, among others, of the Scott-Snell, Sale-Onslow, Millenium, Grätzin, Pharos, and Keith and Blackman systems.

In the last-named system, of which I am privileged to show you quite the latest development to-night, a very compact type of compressor is used, which is driven by electricity, water, or from a belt, as may be desired.

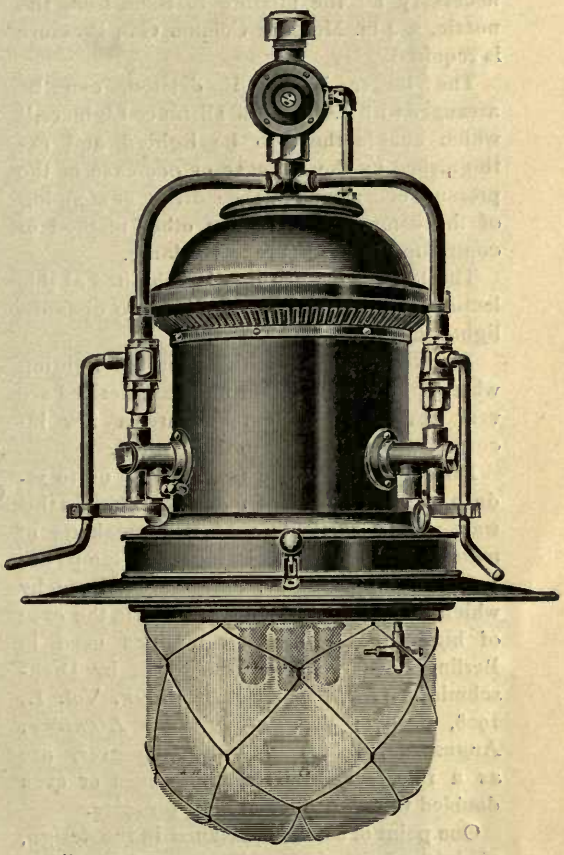
The result of leading gas into the burner at a high pressure is a great gain in efficiency, and pressure as high as 55 inches of water is actually in use at the present day. For instance, the illumination of Kingsway and Aldwych, on the Millenium system, utilises a pressure of 54 inches, while the Sale-Onslow system at the new Victoria Station, uses 50. The new Keith inverted lamps just installed in Fleet-street are also run at a pressure of about 50 inches. It is true that the Salzenberg lamp, brought out in Germany, utilised a pressure of as much as one atmosphere, but it does not seem to have ever developed into a practical condition.

One point of interest in connection with the Keith apparatus, is a lubricating device, by means of which the compressor, once charged with oil, does not require a fresh supply for some considerable time. The compressor shown at this lecture is fitted with this automatic lubricating device.

The main point of advantage claimed for the inverted lamps, of course, is their high candle-power, as much as 73·6 candles having been obtained by some tests with ordinary town gas. However, only 60 candle-power per cubic foot is claimed by the makers. The lamps are made in all sizes from 60 candle-power to 1,500 candle-power, with single burners.

The high efficiency claimed is said to be obtained to a large extent by means of a pre-heating device, whereby the gas and air mixture is passed through a heater fixed on the bottom of the burner tube, as near the mantle as possible. It takes the form of two shallow cones, fixed base to base, with a diaphragm between, perforated at the outer edges. This has the effect of spreading out the mixture of gas and air over a large area of highly-heated surface before reaching the nozzle. The heating of the gas and air mixture takes place

Fig. 28.



Grätzin Inverted High-pressure Lamp.

progressively, for as the mixture gradually moves forward it is brought into contact with surfaces which are more highly heated than those it has just left. At the same time, the heater has the effect of taking heat from the nozzle, and so prevents it becoming too highly heated at the tip.

An additional effect is obtained by heating the secondary air supply as highly as possible before coming in contact with the mantle. By this means as much of the waste heat as possible is utilized to give a regenerating effect.

To overcome the resistance of the burner, due to the large expansion of the heated mixture, and the high velocity at which it is necessary for the mixture to issue from the nozzle, a 4 in. Mercury Column Gas Pressure is required.

The larger lamps, if desired, can be arranged with "Automatic Distance Lighters," which enable them to be lighted and extinguished by the increase or decrease of the pressure occasioned by the starting or stopping of the compressors, or any other method of controlling the pressure at the lamp.

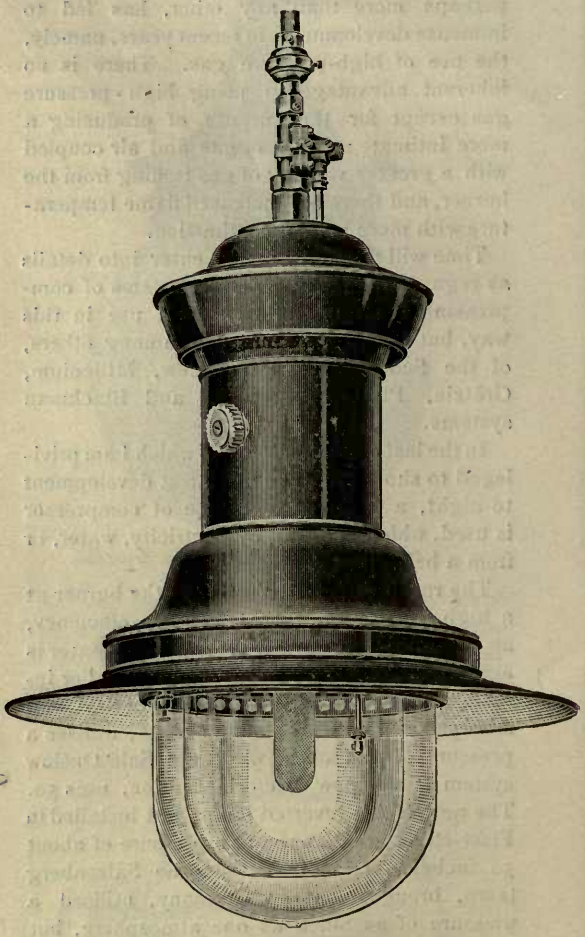
The largest lamp which is exhibited at this lecture is fitted with this automatic distance lighter device.

The advantages of high-pressure lighting where high candle-power units are desired are very obvious, though there are a few inconveniences attached to the method.

No doubt experience is teaching us to reduce the percentage of mantles broken in this way. Some particulars of the breakage of mantles and globes occurring when lamps are switched on suddenly, and the methods by which these troubles were avoided in the case of high-pressure inverted mantles used in Berlin, have recently been given by Drehschmidt. (*Illuminating Engineer*, Vol. I., 1908, p. 951; *Journal of Gas Lighting*, August 22, 1908.) Mantles, however, are as a rule, specially strongly woven or even doubled in order to resist high-pressure.

One point of some importance in the design, of high-pressure incandescent gas lamps, has been the adoption of lanterns containing two or three distinct mantles, giving in all, the same candle-power which a single big mantle would do. This method has several advantages. For one thing, a small mantle is in general not so liable to injury, and lasts longer than a large one; it may, in addition, be more efficient. Again, when three mantles are used, the breakage of one of them is not so serious, as there are two healthy mantles left burning. When there is but one mantle in the lamp, on the other hand, an accident to it puts the light out altogether. Yet another merit of the three-mantle arrangement is that it is possible, at a certain hour at night, to arrange for the extinguishing of two out of the three, thus

FIG. 29.



KEITH INVERTED 1,500 CANDLE-POWER HIGH-PRESSURE LAMP.

effecting a saving without plunging the streets into complete darkness. This method of partly extinguishing the lamps is now used in Berlin, and other towns in Germany.

The Relative Merits of Pressure-Gas and Pressure-Air.—A considerable amount of discussion has recently taken place round the question of the relative merits of using compressed air or compressed gas in the burner; both, as we have seen, are capable of leading to the intimate mixture of gas and air which we desire to produce. Klatte, of the

Pharos Company, has strongly recommended the use of high pressure air, urging several advantages. (*Illuminating Engineer*, Vol. I., 1908, p. 956, and references.) For instance, the original gas pipes can be used, and in the event of anything going wrong with the high-pressure air system, the light is diminished only and not extinguished.

When we use high-pressure gas, on the other hand, an accident to the compressor may have serious consequences, and the tendency to leakage is, of course, greater than with low-pressure gas. In addition, it is urged that the necessity for employing special meters for high-pressure gas, and other inconveniences in supplying the system to private

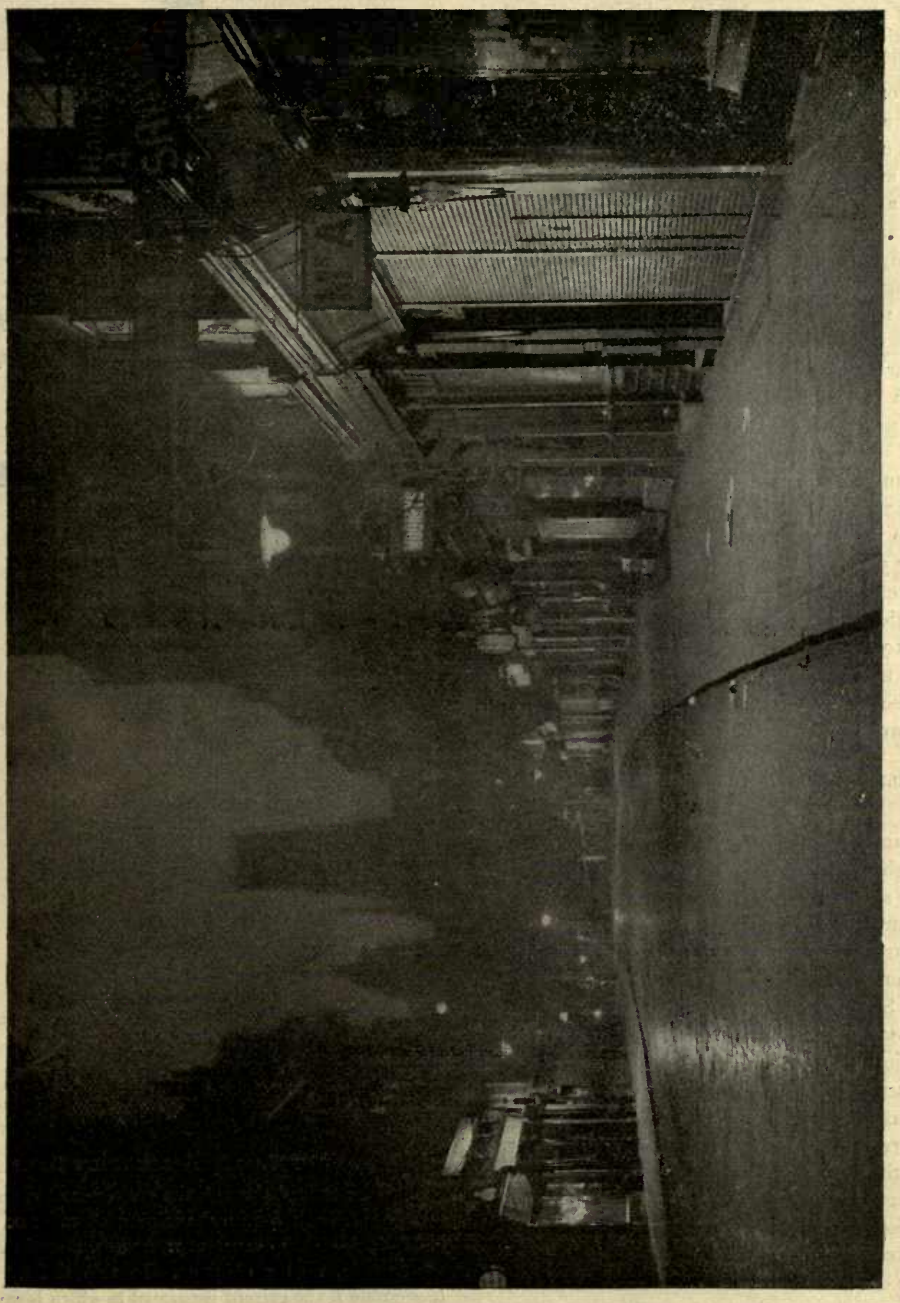


FIG. 30.

ILLUMINATION OF FLEET-STREET BY KEITH HIGH-PRESSURE GAS LAMPS.
(For the use of this illustration we are indebted to the courtesy of the *Journal of Gaslighting*.)

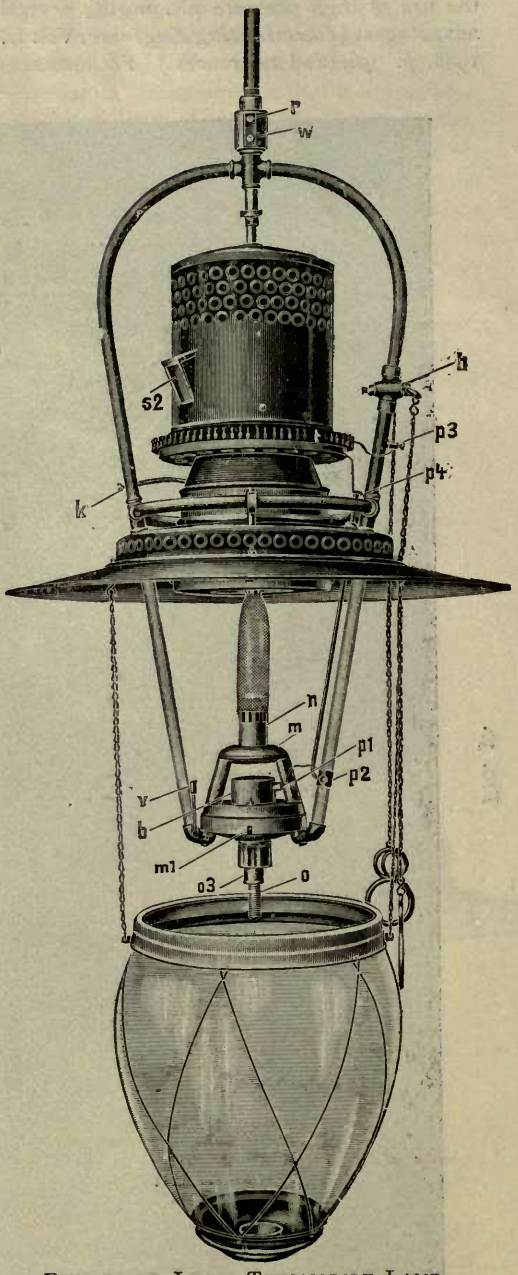
consumers, is avoided by the use of high-pressure air. On the other hand, high-pressure air systems require two pipes, an arrangement which is not always convenient. It is interesting to recall that the method was adopted many years ago by the United Kingdom Lighting Trust in this country, and is still in use at the present day.

Another system to which reference may be mede is the Selas, in which a mixture of gas and air is compressed and supplied to the burner. The system involves the mixing of gas with air, and therefore essentially differs from ordinary high-pressure systems. The gas, coming through the meter, passes into a mixing apparatus, in which it is automatically mixed with air in the proportion of two parts of gas to three parts of air, and this mixture then passes into a compressor, from which it is delivered into the service-pipes at a pressure of 10 inch water-gauge. The chief advantage claimed by the Selas system is its great economy and the variety of burners. The upright burners range from 25 up to 5,000 candle-power, the efficiency being 50 candle-power per cubic foot per hour. This efficiency is claimed to be realised even with the smallest burner. The pressure being only 10 inch water, any ordinary pipes may be used, and the leakage, if there be any, cannot be greater with Selas at 10 inches than with ordinary gas at 2½ inch pressure.

Self-contained Highly Efficient Lamps.

In any case, whether we use high-pressure air or high-pressure gas, it is usually necessary to make some alteration or addition to the system of mains. Attempts have therefore been made to introduce into ordinary gas lamps local pressure raising or regenerative devices. Thus Scott-Snell many years ago devised means of pre-heating the air supplied to the burner and securing a forced draught. Lucas sought to produce an increased draught by the use of special long chimneys, but this simple device rendered the lamp inconveniently long. More recently, the same lamp has been modified by the ingenious application of a thermopile, the junction of which is placed near the flame and supplies current to a small electrically-driven fan at the base of the lamp; while another improvement consists in a device to enable the junction of the pile to get heated without being actually in the hot zone of the flame. It is stated that the thermopile will last 1,000 hours before it requires renewal.

Fig. 31.



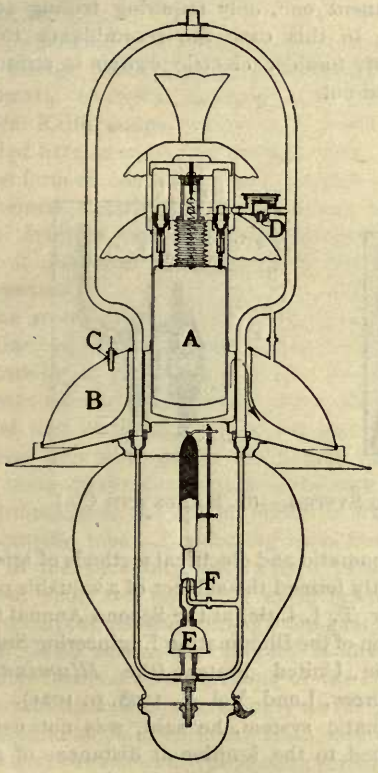
Details of Lucas Thermopile Lamp.

[The gas enters through the regulator at *r*, passes through the cock *h* into the mixing chamber *m*, and finally through the burner at *n*, and so, after heating the mantle, up the chimney. In this is fixed the thermopile *t*, the current generated in which is carried by the wires p_1, p_2, p_3, p_4, to *m*, a small electro-motor, rotating about a vertical axis at a speed of 2,000 revolutions a minute. This motor is coupled directly on to a small fan, which creates the required draught.]

It will naturally be recognised that the heat-resisting properties of the metals used in the thermopile are the chief consideration, and therefore metals like copper, nickel, and aluminium are selected, and the life is considerably prolonged. The current required is but small.

As a result of the air sucked in by the electric fan at the base of the burner, a flame

Fig. 32.



The Chipperfield Lamp.

of very high temperature and a correspondingly high efficiency is obtained. At the same time the cool air drawn in by the fan keeps the base of the burner and the actual working parts cool, and promotes their wearing power.

For this lamp it is claimed that a minimum candle-power of 1,200, obtained at the consumption of only 30 cubic feet of gas per hour, is arrived at. It is also pointed out that the lamp is of comparatively small size, absolutely self-contained, and can be used with any pressure and quality of gas off the ordinary supply pipe.

Yet another type of portable high-pressure lamp is the Chipperfield, which utilises what is equivalent to a small hot-air engine placed above the burner; this automatically pumps air under pressure into the heated reservoir, the combination of increased pressure and pre-heating resulting in a considerable increase in efficiency.

In the top of this lamp there is a movement worked by the waste heat of the burner which causes the air to expand in the cylinder, A, thereby forcing the displacer to rise.

Attached to this displacer are two valves which, when the air displacer is at the highest point, exhaust the expanded air, and when the displacer is at its lowest point draw in cool air. Attached to this displacer there is also a metal concertina which, when on the down stroke, draws in air through an inlet and outlet valve at D, and on the displacer rising the concertina compresses the said air, and passes it back through the above-mentioned valves to a reservoir, B, which takes all the fluctuation out of the light.

The reservoir is fitted with a blow-off valve, C, adjusted to a pre-determined pressure of 32 inches. The lamp is fitted with an air and gas nipple of special design, F, which enables the gas to be regulated by a turn of the cap. The air is regulated by a sleeve on the Bunsen tube. The movement can be replaced in less than five minutes by simply disconnecting one union.

[Since the exhibition of this lamp, fitted with the upright mantle, at the lecture, I have been given to understand that the firm are bringing out an inverted type from which good results have been obtained.]

Liquid Gas Systems.

I may next say a few words about a system of gas lighting which has recently come into prominence, namely, the use of liquid gas of various kinds. To this I may refer again in my next lecture. Compressed gas of this description is mainly employed in cases in which portability is extremely desirable—for lighting railway carriages, &c. The coming of the inverted mantle and the possibility of making mantles which would withstand the vibrations of trains has led to considerable development of this method.

One of the older systems in this country is the Pintsch oil gas system, in which oil gas is subjected to a pressure of about 6 to 7 atmospheres per square inch.

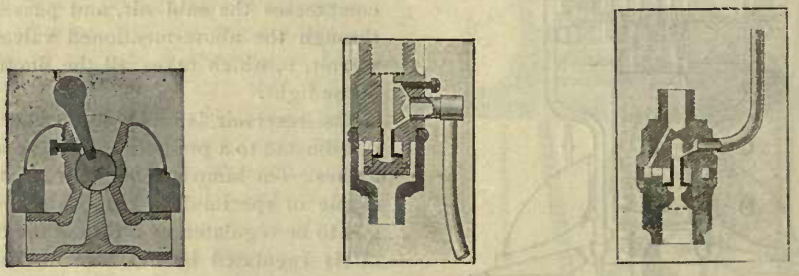
The Blau gas again is a special liquid illuminating gas produced by the distillation of mineral oils, such as crude petroleum; the

gas is in this case compressed at the exceptionally high pressure of 100 atmospheres, 20,000 litres being reduced to the bulk of 50.

Wolf gas is yet a third system of a kindred nature (*Illuminating Engineer*, Vol. I, 1908, page 681); it consists principally of such hydro-carbons as ethylene and ethane, and is claimed to be influenced to an exceptionally small extent by external temperature.

These liquid gaseous illuminants claim exceptionally high calorific value, oil gas being stated by Mr. F. D. Marshall to yield 8,000 to 10,000 units, and Blau gas over 13,000. This may account for the extremely high illuminating efficiency claimed, for it is stated that the equivalent of over 100 candle-power per cubic foot per hour has been obtained by using Blau gas.

FIG. 33.



DETAILS OF THE NORWICH DISTANCE-LIGHTING SYSTEM. (G. HANDS AND CO.)

AUTOMATIC IGNITION AND EXTINCTION.

I now come to one development in gas lighting which will be recognised to be of exceptional importance at the present day, namely, automatic ignition. If there is one respect in which electricity has claimed to possess a great advantage over gas lighting, it has been the ease with which electric lamps are lighted or extinguished. Naturally, therefore, efforts have been made to extend the same facilities to gas lighting.

One of the simplest systems of this kind has been the arrangement, employed in the Norwich system of gas lighting, of which I am enabled, through the kindness of Messrs. G. Hands and Co., to show you an example to-night.

In this system no air tubes or electrical wires are required. The switch itself, being in the form of a bye-pass cock, is inserted in the supply pipe to the fitting which it is required to control, and an automatic valve is applied to the nose-piece of the fitting, for the purpose of directing to its proper course the small quantity of gas which is required for a pilot light.

Thus the actual gas pressure supplied controls the valve in the nose-piece of the fitting, and turning on the full pressure is sufficient to enable the lamp to light up. The manipulation of the lamp inserted in the pipe provides either a bye-pass or allows the gas to flow freely to the burner. The system claims to be a very permanent one, only requiring trifling attention. In this case the resemblance to the ordinary tumbler electric switch is strikingly carried out.

Pneumatic and electrical methods of ignition recently formed the subject of a valuable paper by Mr. T. J. Litle, at the Second Annual Convention of the Illuminating Engineering Society of the United States (the *Illuminating Engineer*, Lond. Vol. I., 1908, p. 1025). The pneumatic system, he said, was not usually supplied to the ignition at distances of more than twenty yards, which is, of course, amply sufficient for an ordinary household, though special pressure-raising devices may be used to act on a lamp in a very large hall. Of course, the pneumatic systems pre-suppose the use of a pilot flame. In passing I may refer to a method of utilising a single pilot flame for the cluster of several mantles in the same lamp.

Another method which has been the subject of a considerable amount of experiment is electrical ignition. According to the usual system the kindling is accomplished by a jump-spark from an induction coil or magneto-generator. At the discussion of the paper by Mr. Litle just referred to, many divergent expressions of opinion were to be noted, some professing to have found the system com-

pletely satisfactory, while others found it very irregular.

It need hardly be pointed out that this is one of those cases in which the gas engineer has found it to his advantage to study the kindred subject of electricity. In the discussion of Mr. Litle's paper it was very generally agreed that previous failures had been largely due to deficient insulation. Failures may also be due to a spark occurring in the wrong position in the burner, and, therefore, failing to ignite the gas.

I am pleased to say that, by the courtesy of Mr. George Keith, I am able to show you the automatic electrical ignition used with the newest Keith lamps, which is, I believe, exhibited here in public for the first time. This latest form of controlling and ignition can be performed electrically, and possesses several novel features, one of the advantages being that it dispenses altogether with the use of bye-passes.

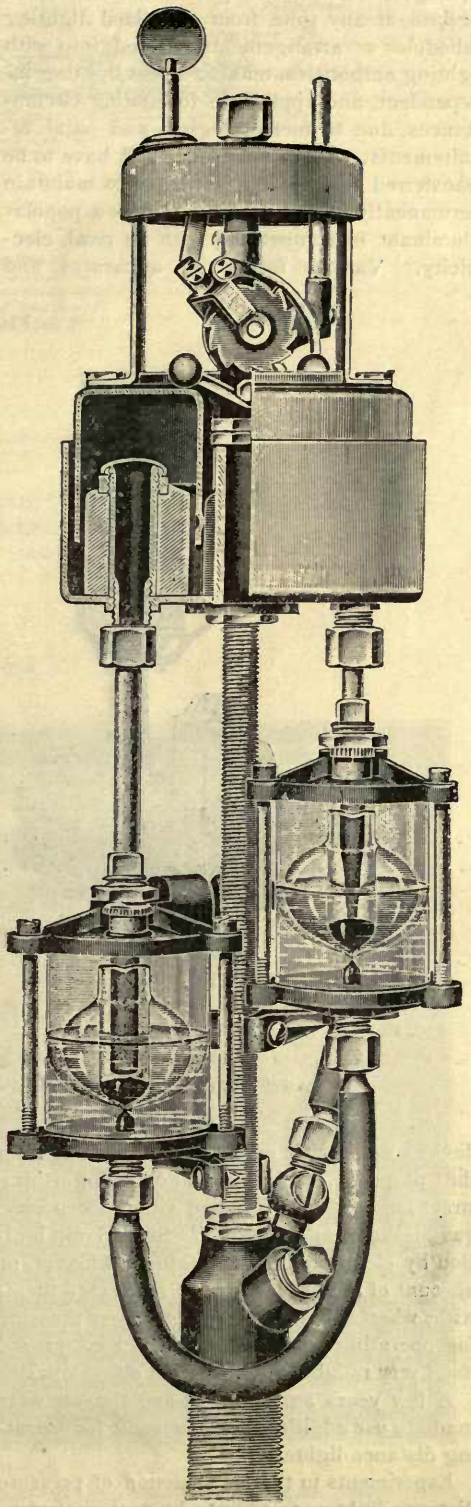
The arrangement on the lamp consists of a tubular body which is part of the down-stem, containing a permanent magnet fitted with a brass valve at the bottom, which drops into a seat and holds it tight by its own weight against gas getting into the burner. Above this permanent magnet is fixed the core of an electro-magnet, the coil of which is fixed on the outside tube. Conducting wires from one pole of the necessary battery fixed in a convenient spot are taken to each lamp, the return current passing through the gas-piping itself. The permanent magnet is therefore lifted or repelled by the passing of the current in certain directions, accordingly as the gas is required to be on or off in the lamp, and at the same time the same current passing through the platinum filament contained in a small chamber fixed on the burner nozzle ignites the gas.

It is hardly needful to point out that any automatic system for lighting interiors must be absolutely reliable. A very wide field, however, has been opened out in the automatic control of public lighting in the street.

Street lighting forms an essential part in the revenue of gas works, and therefore it demands a great share of consideration, not only on account of this revenue, but also because of the safety of public thoroughfares. This is particularly the case on account of the improvements made in electric lamps and the consequent increased competition of electric light.

With electric illumination all, or nearly all, lamps are operated from a central point. This

FIG. 34.



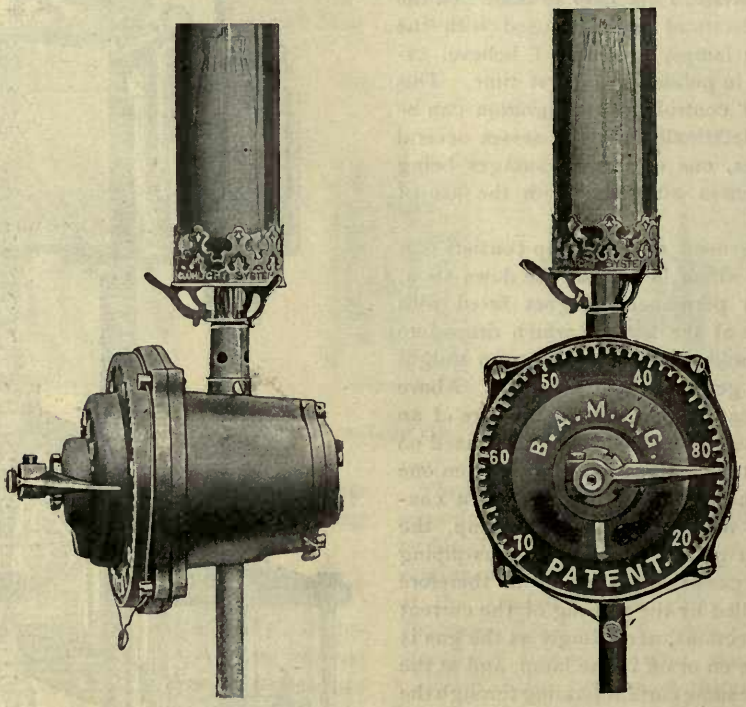
THE ROSTIN AUTOMATIC DISTANCE LIGHTING AND EXTINGUISHING APPARATUS.

arrangement makes it possible, if desired, to deviate at any time from the fixed lighting schedules or arrangements entered into with lighting authorities, making street lighting independent, and applicable to existing circumstances, due to meteorological and local requirements. These conditions will have to be transferred to gas, if gas wishes to maintain permanently its acquired position as a popular illuminant in competition with its rival, electricity. Various forms of apparatus and

kinds, one with a diaphragm, and one with a float or cup, on which the wave can exert its force. Some particulars of the use of the Alder and Mackay system in Tipton have been given by Stephenson (*Journal of Gas Lighting*, March 10th, 1908), who found that a very great saving in labour and in breakages of mantles, rods, and glasses was achieved by the introduction of the system.

In this case an increase of pressure of 1 in. to 1½ in. was maintained for about half a

FIG. 35.



"BAMAG" AUTOMATIC DISTANCE-LIGHTING AND EXTINGUISHING APPARATUS.

devices were resorted to a few years ago for the purpose of lighting and extinguishing street lamps. They utilised either electricity, gas pressure, or clockwork. Street lamp ignition by electricity has not yet found favour, on account of the great expense connected therewith, whereas the employment of gas pressure for operating distance-lighting has proved itself very reliable and free from objections.

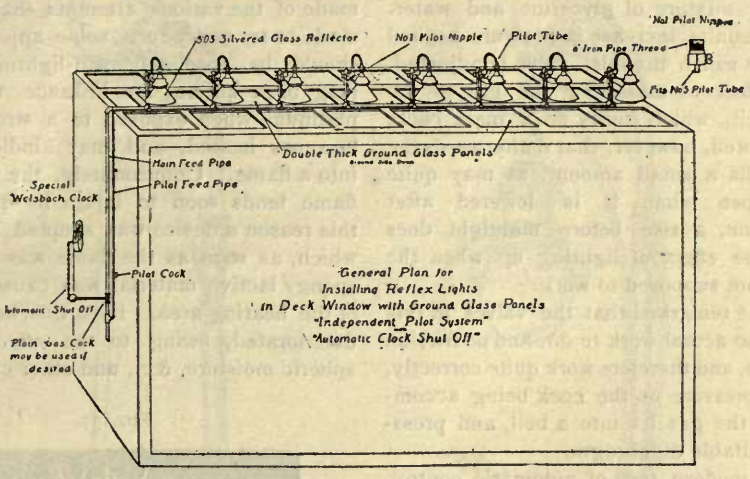
A few years ago, the first experiments were made to use additional gas pressure for operating distance-lighters.

Experiments in the construction of pressure distance-lighters to operate by pressure waves led to the result of constructing two main

minute to a minute and a-half, and the wave seemed to travel practically instantaneously. An interesting result of this pressure-raising method is that at a certain hour of night, when the public lamps are extinguished, the lights of private consumers are also temporarily affected. It is stated that no objections were raised on this score; indeed the consumers rather welcomed this gratuitous information that midnight was at hand.

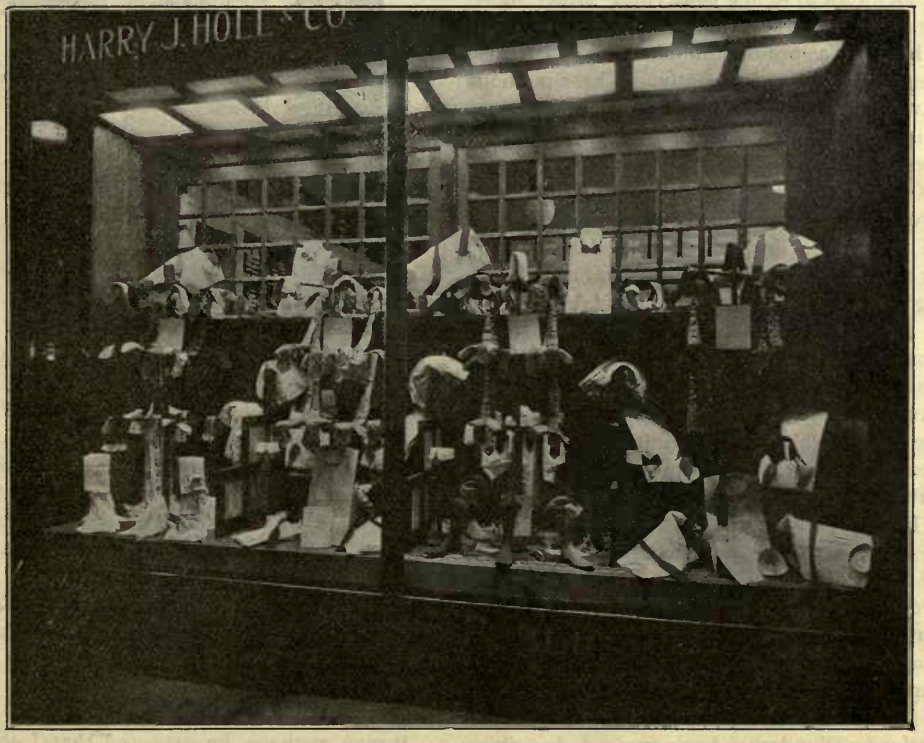
A very interesting automatic lighting and extinguishing apparatus for street lamps, is that of Dr. Rostin, which is employed very extensively in this country. In this case, the automatic arrangement consists of two valves

FIG. 36*a*.


No1 Pilot Nipple
Pilot Tube
Fits No3 Pilot Tube
Double Thick Ground Glass Panels
Main Feed Pipe
Pilot Feed Pipe
Special Welsbach Clock
Pilot Cock
Automatic Shut Off
Plain Gas Cock may be used if desired
General Plan for Installing Reflex Lights in Deck Window with Ground Glass Panels "Independent Pilot System" "Automatic Clock Shut Off"

METHOD OF LIGHTING SHOP WINDOWS BY GAS; LIGHTING CONTROLLED BY AUTOMATIC CLOCKWORK ARRANGEMENT.
(The Welsbach Co., New Jersey, United States.)

FIG. 36*b*.



PHOTOGRAPH OF WINDOW ILLUMINATED BY SYSTEM SHOWN IN FIG. 36*a*.
(The Welsbach Co., New Jersey, United States.)

which float in a special non-freezing and non-evaporating mixture of glycerine and water. A certain definite increase in pressure beyond the point to which the inlet valve is adjusted, has the effect of admitting the gas to the working bell, which turns on a main cock. It will be noted, however, that if afterwards the pressure falls a small amount, as may quite likely happen when it is lowered after lighting time, a rise before midnight does not have the effect of lighting up when the lamps are not supposed to work.

It may be remarked that the valves in this case have no actual work to do, and no friction to overcome, and therefore work quite correctly, the actual pressure on the cock being accomplished by the gas let into a bell, and pressing on a suitable diaphragm.

Another modern type of automatic control, depending on a wave of pressure, is the Bamag system, which I am also privileged to show here to-night. In this case, the exact pressure at which it is desired that the apparatus should regulate, may be adjusted by setting the pointer on the dial, and the apparatus can be controlled either by a rising or falling wave of pressure.

Clockwork systems controlling street lighting, by which the lamps are turned out and lighted at a pre-determined hour, have also been utilised very frequently. These methods have certain advantages, being, perhaps, more reliable than others depending on a wave of pressure.

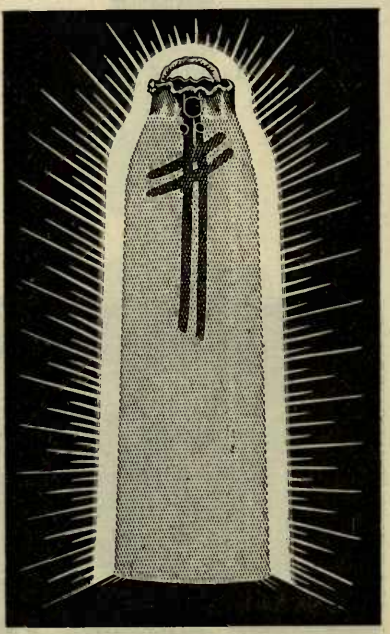
On the other hand, they have the disadvantage of being too automatic; they turn on and off the light at a certain hour, but on an exceptional occasion, for instance, when a fog is on, they, of course, do not take account of the fact, whereas an instrument controlled from the station can be made to do exactly what is wanted. Such clockwork methods have, however, also found a field for advertising signs, which can be left burning on the premises without the shopkeeper or his assistant being actually there. (Figs. 36*a*, 36*b*.)

Perhaps, in passing, reference may be made to the discovery of Welsbach, that a mixture of finely divided iron and cerium in suitable proportions yields sparks when rubbed; it is anticipated that an automatic lighting device may be based on this principle, but the apparatus is not yet in a commercial stage.

[Since the delivery of this lecture a communication by Wunderlich has appeared, describing the practical application of a very similar process, *Journal für Gasbeleuchtung*, May 15.]

Before leaving this subject mention may be made of the various attempts that have been made to try to produce some apparatus which should be absolutely self-lighting. It has long been known, for instance, that spongy platinum, when exposed to a stream of gas, becomes heated, and may kindle the latter into a flame. Unfortunately, the heat of the flame tends soon to injure its quality. For this reason a device was adopted by means of which, as soon as the flame was lighted, the spongy lactive material was caused to fly out of the heating area. Even this, however, soon deteriorated, owing to the effect of atmospheric moisture, &c., and other causes.

FIG. 37.



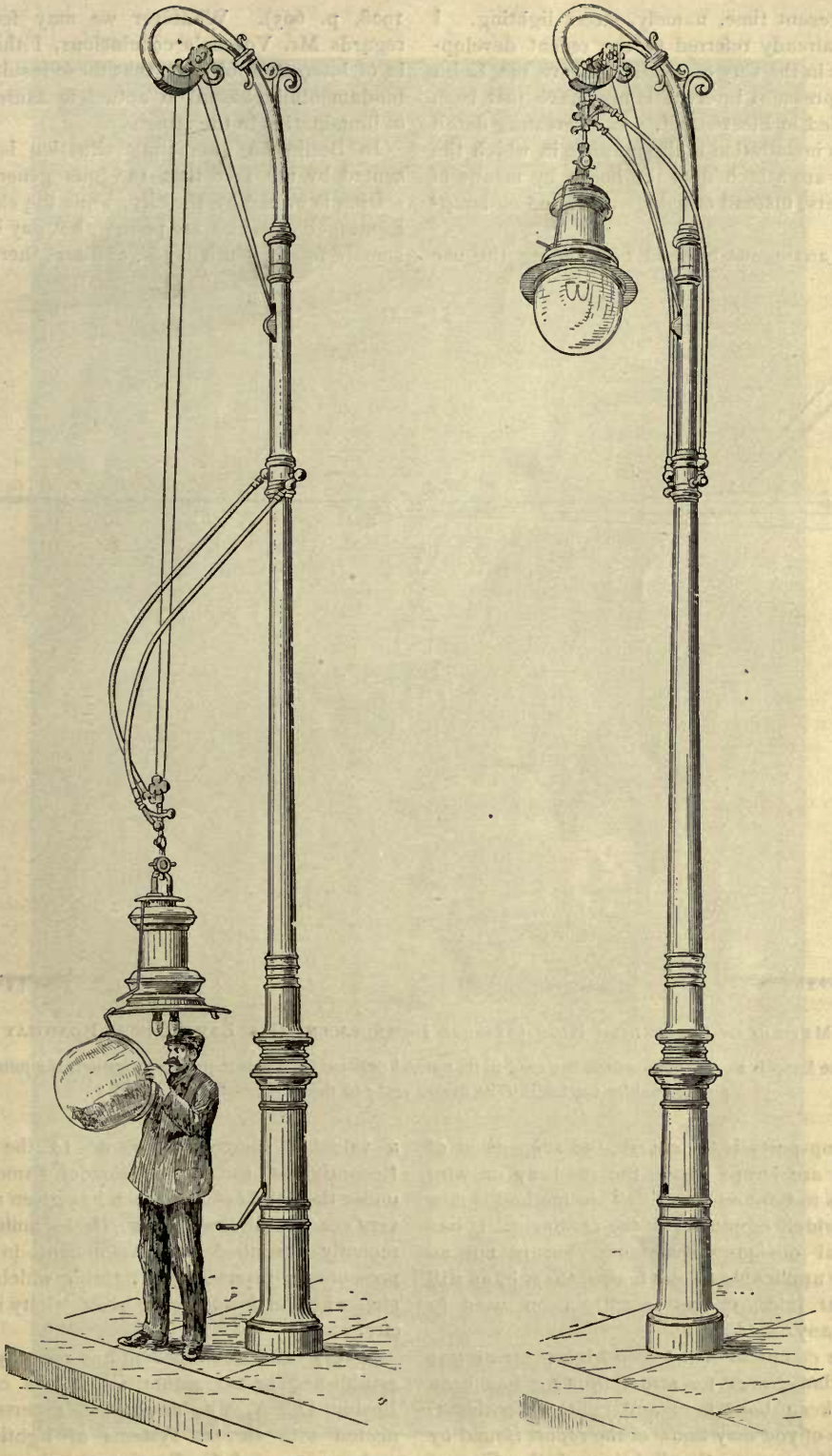
SELF-LIGHTING MANTLE. (J. MAYER.)

To-night I have on exhibition one of the newest types of self-lighting gas mantles of this kind, which is said to be exceedingly permanent if certain illuminatory precautions in the use of the mantle are taken. I am informed, however, that some difficulty may be experienced in applying this device to very poor gas containing but few hydro-carbons. However, we can regard this only as an interesting attempt to solve the problem.

STREET LIGHTING.

It may, perhaps, be expected that I should say a few words about one use for gas lighting which is receiving considerable attention at

FIG. 38.



ARRANGEMENT ENABLING HIGH-PRESSURE GAS LAMPS TO BE LOWERED IN THE STREETS TO RECEIVE ATTENTION. (MESSRS. EHRICH AND GRÄTZ, BERLIN.)

the present time, namely, street lighting. I have already referred to the recent developments in the City of London, where the Keith high pressure inverted lamps have just been installed in Fleet-street. An interesting detail of this installation is the manner in which the lamps are attached to the house by means of brackets, instead of being suspended on lamp-posts.

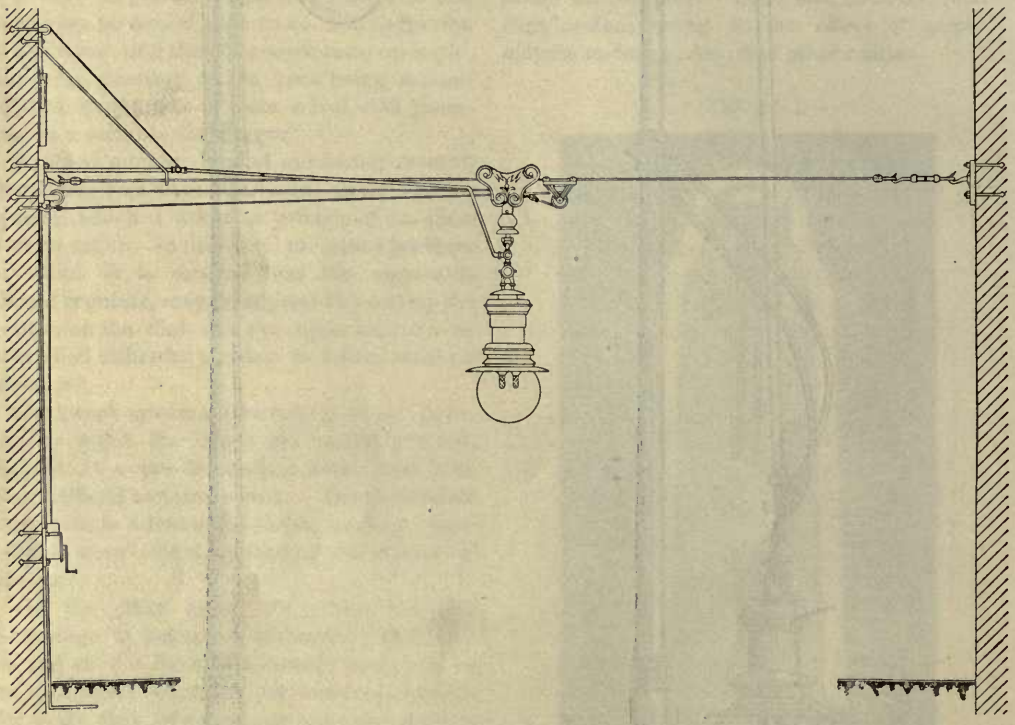
An analogous method of avoiding the use of lamp-posts is, of course, the suspension of flame arc lamps above the roadway on wire cables in Cannon-street. This method is now very widely employed on the continent. It has several obvious advantages but is not so easily applicable to gas lamps, though, as will appear later, it has recently been used in Germany.

The competition between high-pressure gas and flame arcs for street lighting has been very keen both here and on the Continent. Many of you may know of the report issued by Mr. Voysey on the lighting of the City of London (*Illuminating Engineer*, Vol. I, 1908, p. 605). Whatever we may feel as regards Mr. Voysey's conclusions, I think it is of interest to observe that these results are fundamentally based on actual measurement of illumination in the streets.

In Berlin an interesting situation is presented by the fact that the gas generating station is owned by the city, while the electric lighting companies are private, but pay handsomely for their privileges, and are, therefore, a valuable source of income to the city. Recently the use of the Blondel flame arcs under the hands of Dr. Bloch has given rise to very good results, while Dr. Drehschmidt has recently described the developments in high pressure in inverted gas lighting which kept step with the development in electricity in this city.

A very valuable precedent has recently been established by the authorities in the city of Boston, U.S.A., who dispatched experts connected with various systems of lighting to make a tour of the Continent and report on existing methods of street illumination, be-

FIG. 39.



METHOD OF SUSPENDING HIGH-PRESSURE INCANDESCENT GAS LAMPS ABOVE ROADWAY

(The lamp is shown hung across the road in its normal position. When requiring attention, the jointed piping enables the lamp to be drawn aside to the pavement and lowered.)

FIG. 40.

VIEW OF STREET IN STUTTGART (GERMANY) ILLUMINATED BY INCANDESCENT GASLAMPS SLUNG ACROSS THE ROADWAY.

fore taking any decision on the matter. It need hardly be pointed out how essential are the services of *experts* in order to prepare reliable data for the guidance of municipal authorities, and the city will doubtless reap the benefit of their foresight.

[Since the delivery of this lecture a deputation appointed by the Streets Committee of the Corporation of London has paid a visit to the Continent, with the object of examining the lighting of the chief cities in Europe, and has published its experiences. The method of street lighting preferred by the deputation consists of inverted high pressure incandescent gas lights, centrally placed in the street and equipped with raising and lowering apparatus; where this is not possible electric lighting is recommended.

The suggestion that high pressure incandescent gas lamps should be raised and lowered for attention in the same way as arc lamps is somewhat novel, and has given rise to some surprise; I have nevertheless recently seen and had an opportunity of inspecting a form of apparatus which is now being manufactured by Messrs. Ehrich and Grätz, in Berlin, and which is said to enable this to be satisfactorily accomplished.

I have also had an opportunity of observing this system in the experimental stage in the streets of Stuttgart, in Germany. I have, however, been informed by several Continental experts that the method is not yet so satisfactory in the case of high-pressure gaslighting as it has been found to be in the case of electric arc lamps. A considerable amount of experiment has been necessary in order to make the arrangement practicable, and to avoid possible leakage at the joints, deposits in the piping in winter, corrosion, &c. Formerly a flexible tube, enabling the lamp to be lowered, was used, but more recently it has been found preferable in Stuttgart to employ a jointed gas-pipe, and to arrange for the lamp being brought to the side of the street, before being lowered. In Stuttgart, both high-pressure gas and high-pressure air systems have been used, the latter, however, necessitating the use of two distinct pipes to convey the gas and air respectively.

In adopting a system of this kind, however, it must be borne in mind that the polar curve of light-distribution of flame arc lamps differs considerably from that of incandescent gas-lamps, and that the method and height of suspension that is found satisfactory for the one, may not be equally so in the case of the other. And, in addition, it may be suggested that when it is found desirable to instal high-pressure gas lamps fairly low down in the streets, they should be equipped with some form of diffusing globe; otherwise the effect is apt to be glaring. It may be mentioned that this deputation did not contain any experts connected with the various methods of lighting examined; therefore, while recognising the importance of the precedent established by municipal authorities studying for themselves systems of illumination, one must be cautious in advocating too sudden and extensive modifications in existing systems of lighting the streets of London, as a result of their experiences.

It need hardly be said, moreover, that it would be unwise to attempt the lighting of all varieties of streets on any uniform special plan such as that outlined above, and it is to be noted that further experiments in the streets of London are to be conducted before any final decision is taken. The question is who ought to undertake these tests, so that we may accept the results as unbiassed?]

A Calorific Standard.

Prof. Morris in a recent article suggested that entirely different results would naturally be obtained if the gas used was London gas, or the much richer gas employed in Edinburgh. This leads one to comment on what is now felt to be a rather curious anomaly in the present conditions of gas testing, that we still test gas in terms of its illuminating value, while, as a matter of fact, now that incandescent gas mantles are so widely used, it is the calorific value in which we are mainly interested.

The question has already arisen how far we shall continue to abide by the legislation of the past, or whether we shall not eventually entirely abandon the test of illuminating value, and be content with producing non-luminous gas of a high calorific value producible at a distinctly cheaper rate.

This matter has been the subject of much discussion in this country, and very careful consideration in the United States, where a recent Committee of the American Gas Institute reported upon it at great length. I believe that in Chicago a calorific standard has already been set up.

In this country, legislation of recent years has made several concessions to this point of view. For instance, in 1900 the South Metropolitan Gas Company succeeded

in promoting a Bill authorising them to reduce the illuminating value of their gas from 16 to 14 candles, and last year a notable step was undertaken by the Edinburgh and Leith Gas Commissioners in agreeing, in accordance with Mr. Herring's recommendation, to reduce the candle-power of the gas in that town from the high value of 20 to 14. The Gas Light and Coke Company have also now definitely recognised a calorific test in addition to tests of illuminating power.

Although this method of insisting only on an illuminating value of gas, when calorific value is all important, may seem rather strange, yet there are certain difficulties which will probably lead to only a gradual change in existing regulations. For instance, it is urged that one of the chief advantages of adhering to a standard of illuminating value is that any appreciable percentage of inert gas is immediately detected by the decrease in illuminating value.

Although an immense amount of work has been done on the subject of gas calorimetry in this country, it seems to be admitted that the process is far from being such a simple one as the illuminating test at present employed, and that until recently sufficiently accurate instruments for the purpose were not available. However, there are indications that a change will soon come.

In Germany, too, I was given to understand by Dr. Drehschmidt that calorific tests are regularly undertaken by the gas company in Berlin, and a systematic record of the qualities of the gas, in this respect, constantly kept, in order that any deterioration in heating value may be immediately recognised and detected.

I notice, however, that Herr Lebeis, in a paper recently read in Berlin, and reported in the *Journal für Gasbeleuchtung* (August 14), remarks upon the fact that in different districts both the pressure and the calorific value of the gas supplied are often found to differ very considerably; consequently a type of burner which is satisfactory in one locality may not be equally so in another. The same point is emphasised in a recently published address of Mr. H. O'Connor (*Gas World*, Aug. 14), who indeed goes so far as to assert that "a burner which was a good one in one town might be an absolute failure in another."

Lebeis describes an interesting modification of the incandescent burner which is intended to avoid this difficuly, and which he terms the "Aerostat." This consists essentially of an arrangement covering the inlet holes of the burner which contracts and expands with the heat, admitting more or less air, and automatically maintaining the most favourable conditions for combustion. In this it seems to resemble the thermostat described by Litle and Whitaker in the United States. (See p. 30). Besides allowing for differences in calorific value and pressure of the gas supplied, this arrangement is also intended to compensate for the alteration in the conditions which prevail when the burner has only just been lighted and is cool, and those which are present when it has reached its normal hot state. These new burners are made for small candle-powers, as low as 33 mean hemispherical candle-power.

[This matter of a calorific standard has just been commented upon in the annual address of the President of the Gas Institute, who foresees its ultimate adoption. A very interesting paper by Mr. C. Forshaw, delivered on this occasion, illustrates most forcibly the fact that there are other factors, apart from calorific value, such as flame-temperature, shape, and volume, which affect the performance of an incandescent gaslight. Mr. Forshaw also demonstrates how the incandescent illuminating power of two gases, hydrogen and carbon monoxide, may be very different under apparently similar conditions, even though both have approximately the same calorific value. Mention may also be made in this connection of the exhaustive experiments of M. Sainte Claire Deville, who has recently published an article in *The Illuminating Engineer*, July, 1909, summarising his views on the subject.]

Relations between Company and Consumer.

In my first lecture I referred to the valuable work of the Boston Edison Electric Illuminating Company, in assisting the consumer and undertaking to advise him how to use his lights to the best advantage.

This attitude has also been adopted by gas companies in the United States, and, I am happy to observe, by the most enterprising companies in our own country as well. For instance, the Gas Light and Coke Company and other companies here fully realise the necessity of keeping the consumers thoroughly satisfied, and undertake for a small charge to maintain their gas burners and mantles in a satisfactory condition.

The educational value of such a provision is proved by the fact that consumers not infrequently eventually learn something of the

adjustment of burners and mantles from the company's representative, and prefer to save money by undertaking the supervision themselves. On the other hand, it must be confessed, that they do not always realise the real economy of renewing mantles promptly as soon as the candle-power has begun to fail.

The Gas Light and Coke Company make a practice of renewing mantles when their initial candle-power has dropped 25 per cent. This usually occurs after about 200 hours burning. We have thus an interesting analogy to the "useful life" of glow lamps, which is usually assumed to be the time that elapses before their candle-power is reduced by 20 per cent. from their original value.

The Company still undertake the supervision of some 200,000 burners, and it is probable that very many more customers will now look after their own installations who were originally educated by the Company to do so. It is also interesting to learn that the Company make a practice of thoroughly testing mantles supplied to customers, by a rigid specification involving both tests of life and candle-power, and showing resisting power against vibrations.

In my present lecture I think I have said sufficient to indicate the exceedingly wide scope and scientific nature of the problems with which the gas profession has now to deal, and the enterprising manner in which many of them have been met during the last few years. In conclusion, I would like to emphasise one point which follows as a natural consequence, namely, the necessity for making provision for the adequate education of the young men of the future.

During the last year a great figure in the gas industry, Sir George Livesey, has passed away, and I think some mention might be made on this occasion of the admirable decision of the Gas Institute, and those who attended a special meeting with the object of honouring his memory. It was decided to create a professorship of gas engineering in his memory at Leeds University; the necessary arrangements have now been made, and this professorship may be regarded as an accomplished fact.

I hope that this will lead to the prosecution of many researches of great value to the industry with which Sir George Livesey was so long associated, and that manufacturers will promote the welfare of the scheme by encouraging those who take advantage of these facilities.

Lecture III.—Delivered March 1, 1909.

LIGHTING BY CANDLES, OIL, ACETYLENE, PETROL-AIR GAS, ALCOHOL, AND OTHER ILLUMINANTS.

Introduction.

In my two first lectures I have dealt with gas and electric lighting. I now propose to deal with systems of lighting which, naturally, lack some of the advantages associated with these highly-developed methods, but yet have themselves certain advantages, and notably those of portability, of being self-contained, and to some extent independent of the supply of fuel from without.

Both candles and oil lamps are of very ancient origin. Dr. Böhm (*Illuminating Engineer*, February, 1908) remarks that oil lamps of a kind were met with in the most ancient Roman illustrations, while splinters of resinous pine were used even in the age of Homer. Candles apparently were of Phœnician origin, and the Emperor Constantine is said to have illuminated Byzantium by candles on Christmas-eve in the fourth century. It is remarkable to reflect how comparatively stationary the manufacture of candles seems to have been until the last century, when the production of stearine and the ingenious invention of a wick that did not require snuffing made the candle a more practical article; it is, however, still worthy of remark that one of the witnesses (a member of a prominent firm engaged in the candle-making industry) examined before the Commission on the standard candle of this country so late as 1881, confessed that he had never contemplated any tests of illuminating power. The treatment of the wick, the quality of wax, and other details, were the subject of very careful attention, but it hardly seems to have been adequately realised that the main business of a candle was to give light.

Dishes of liquid oil and fat were employed even by the most ancient nations; we find that they were used mainly for purposes of ornament rather than for the purpose of providing actual illumination. Indeed, this use of the oil lamp prevails in many churches at the present day. I may mention as an illustration the lighting of Santa Sophia, a church in Constantinople, which Mr. J. B. Fulton recently described in an article in the *Illuminating Engineer*.

Candles, too, are still very frequently employed for decorative purposes, and for the religious and other associations connected with them, sometimes forming an essential part of the ceremonial.

In this connection I may refer to a remarkable book recently published in Vienna by L. von Benesch, in which an extremely interesting collection of ancient illuminating apparatus, including many tasteful designsof candle holders, oil lamps, &c., dating from the Middle Ages to the nineteenth century, is described and illustrated.

Oil Lamps.

The discovery of oil in America about 1860 led to the development of the petroleum lamp proper. Yet the early lamps were not vastly better than those that preceded them. For instance, it was not at once that wicks were devised capable of drawing up the oil from below in a satisfactory manner, and therefore lamps were provided with a reservoir placed at a higher level than the flame, thus allowing the oil to be fed by gravity. The invention of the chimney by Argand, and the draught so produced, was again a great improvement, and the substitution of a ring-shaped wick for the flat variety previously used was also an advance. Oil lamps, however, formed the standard method of illuminating streets before gas was available.

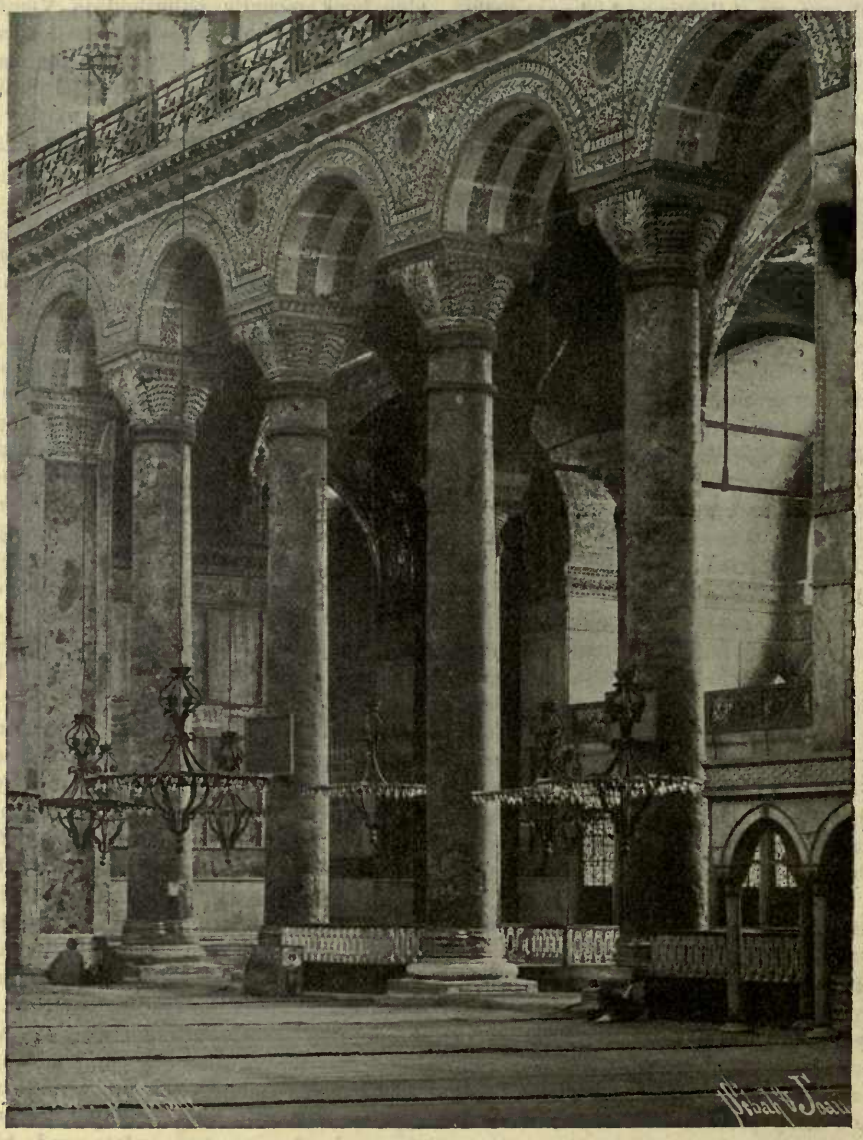
The ordinary petroleum lamp is often unjustifiably condemned for certain defects which are not inherent in it, and can be avoided by suitable design. In country districts the lamps are so widely used that there is still room for the careful study of the best methods of producing and utilising the light produced from oil even at the present day. This matter formed the subject of discussion at the International Petroleum Congress held at Bucharest in 1907, when papers were presented by M. Aug. Pihan, Herr Proessdorf, and myself. A resolution was moved after my paper asking that the Congress should study and decide upon a type of domestic lamp fulfilling the conditions of the greatest safety and highest efficiency; and this suggestion was formally adopted.

This question of safety is indeed a very vital one to the success of oil lamps, and previous to the Congress many prizes had been offered for a lamp which would satisfy the required conditions, but without one being dis-

covered which was considered worthy of the prize.

It may also be pointed out that the design of any particular lamp must take into account the nature of the petroleum which is intended to be used with it. For instance, a lamp intended for American oil would not serve equally well for use with the Russian variety, nor, probably, would the type of chimney favouring the best conditions of combustion be the same in the two cases. The result of trying to burn a variety of petroleum different from that for which the lamp is designed, will probably only lead to the production of incomplete combustion, a smoky flame, and a smell.

FIG. 41.



ILLUMINATION OF CHURCH OF ST. SOPHIA BY SMALL OIL-LAMPS.

Recognising this fact, the Roumanian Government, last year, I believe, introduced legislation specifying the exact conditions to be fulfilled by oil used for illuminating purposes in that country. Naturally, such a specifica-

tion can only be applied to the Roumanian type of oil, and might not answer if used in connection with the Russian or American variety.

M. Pihan, on this and other occasions, has presented details as to the correct method of testing oil lamps, and the paper by Herr Proessdorff, in which 150 lamps were examined, is a useful record of the research on lamps burning petroleum of different kinds that has recently been carried out.

Another very interesting point was touched upon by M. Guiselin (*Illuminating Engineer*, Vol. I., March, 1908), who demonstrated how greatly the light from an oil lamp was affected by the quantity of oil in the reservoir. An increase of 20 per cent. in the illuminating efficiency can be secured by keeping 700 cubic centimetres of petroleum in the reservoir, instead of 500. This can be easily understood when we remember the need to facilitate the capillary action of the wick. Consumers are, therefore, recommended to keep their lamps well filled up.

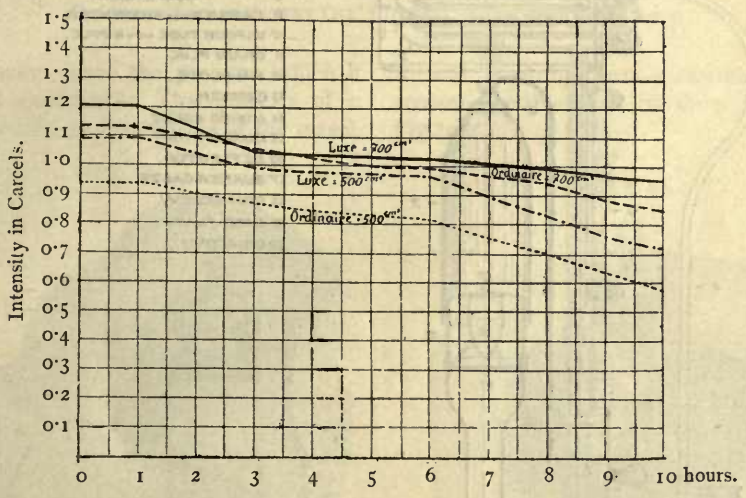
Some very complete researches on the oil lamp as a standard, were communicated by Dr. A. H. Elliott at the second annual Convention of the Illuminating Engineering Society last year, and in the discussion the importance of careful attention to the wick was dwelt upon. One of the speakers referred to a new non-combustible asbestos type. I have the privilege of showing you to-night a new type of non-combustible wick, due to Dr. B. Monasch, and composed chiefly of carborundum. This same authority has recently contributed a study of the ordinary kitchen oil lamp, and has pointed out that the reflector commonly provided with these lamps is of faulty design.

Incandescent Oil Lighting.

The coming of the incandescent burner suggested a new method of utilising liquid fuels. It had been realised that if a liquid illuminant could be vapourised and mixed with the correct proportions of air, it might be utilised to heat an incandescent mantle, to even greater brightness than is obtained by gas of the ordinary variety, according to the calorific power of the vapour generated. One of the earliest methods of utilising petroleum in this way was the Kitson system, according to which the petroleum was compressed at about 50 lbs. to the square inch in a suitable vessel, and then forced through a soft brass tube of very small bore into a heating vessel, and subsequently through a needle orifice to a suitably-designed Bunsen burner. This system has found a considerable field for lighthouse illumination, and especially in isolated positions for which a self-contained portable method of generation is desirable.

The most recent example of the Kitson

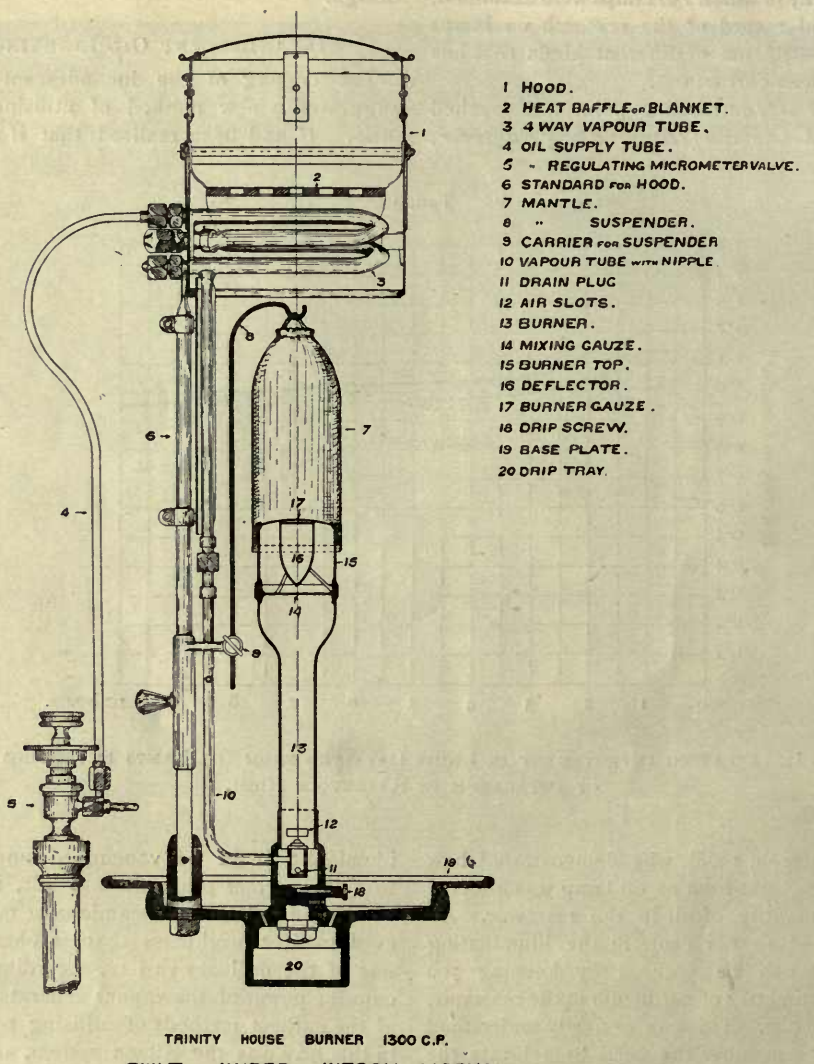
Fig. 42.



Curves Illustrating Improvement in Light Obtained from Oil-Lamps by keeping Level of Petroleum in Reservoir High.

system, the Empire Light, sold in England by the United Kingdom Lighting Trust, is an entirely portable, self-contained lamp, in which an improvement is introduced by arranging the heating vessel in a vertical position quite close to the burner instead of above it.

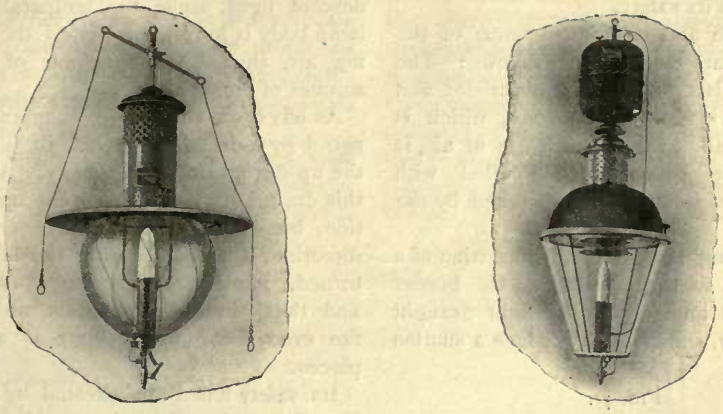
FIG. 43.



SECTIONAL BLOCK OF KITSON BURNER.

The Blanchard system again utilises a self-contained lamp equipped with an inverted mantle, a special feature being the existence of a second vapourising chamber in which the heavier fractions of the oil can fall and be vapourised by their close connection with the mantle itself. It is claimed that one gallon of low quality paraffin oil in connection with the mantle used in this lamp will give an illuminating capacity of 18,000 candle hours. The use of an inverted burner also enables small units to be supplied with greater ease, lamps yielding from 75 to 1,200 candle-power being available. An ingenious and interesting device used in this lamp is the method of registering the level of liquid in the vapouriser, which must be entirely closed and so adjusted as to

FIG. 44.



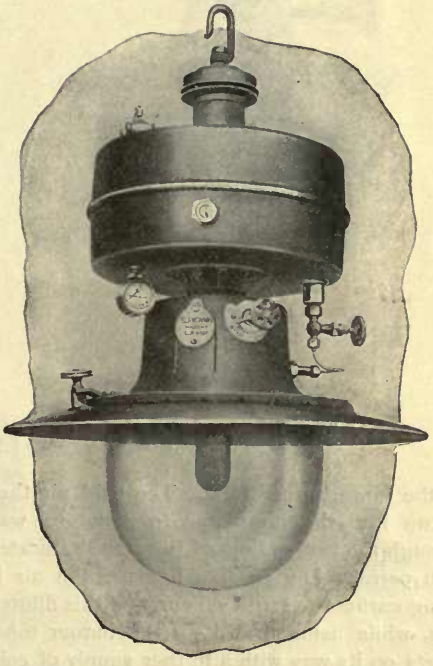
FORMS OF INCANDESCENT OIL LIGHTS. (THE EMPIRE LIGHT.)

withstand many times the pressure which it is likely to experience. This consists of a magnetic needle on the outside of the vessel, which is controlled by a magnetic float rising and falling with the liquid within. Lamps for outdoor lighting are stated to burn 20 hours without requiring further attention. A convenient portable form of lamp is shown in Fig. 45.

FIG. 45.

BLANCHARD PORTABLE TABLE LAMP.

FIG. 46.



BLANCHARD, LAMP HIGH CANDLE-POWER, COMMERCIAL FORM.

The *Petrolite Lamp*, an example of which I have also on exhibition here to-night, represents another development in this direction. In this lamp the air is sucked through a porous vessel impregnated with suitable hydro-carbons, a draught being provided by the use of a

fairly long chimney. One advantage claimed for this lamp is its safety.

The principle and *modus operandi* of the petrolite lamp are essentially as follows:—The container consists of a highly absorbent and incombustible stone. This stone, which is perforated to allow for the passage of air, is placed in the container and filled with petrol, which is immediately absorbed by the stone.

When lighting the lamp, the insertion of a lighted match in the opening of the burner gallery causes immediately a slight draught in the chimney, sufficient to produce a suction

Fig. 47.

The Petrolite Lamp.

in the inner burner tube. The cold air thus drawn into the lamp has to make its way through the perforation of the stone saturated with petrol. During this passage the air is being carburetted with vapour, and this diluted gas, while being drawn up the burner tube, meets on its way with a further supply of cold air from the outside. Both are automatically mixed in the exact proportion to give a very hot Bunsen flame with perfect combustion.

It is therefore suggested that the evaporation of the petrol in the lamp is not produced by heat, but by causing a draught of cold air to pass through the petrolite container. In this way the burner produces a sufficiently hot Bunsen flame for the most brilliant incandescent light, while the temperature of the lamp body is lower than that of the surrounding air, thus eliminating one of the many sources of danger.

As has been shown, the evaporation of the petrol by a draught of cold air is caused by the up-draught of the chimney. As, however, this draught can only act in the upward direction, but never in a sideways or downward direction, it is claimed that the lamp, if overturned, immediately becomes extinguished, and that, therefore, there is no danger of fire even if the whole lamp is smashed to pieces.

Its safety has been attested by the British Fire Prevention Committee, while it has also been approved by the London County Council as an emergency light for theatres and other places of public entertainment.

This lamp has been subjected to very exhaustive tests by Professor J. T. Morris, who found that it gave a 40 candle-power light for one hour on 1½ ozs. of ·695 spirit at 1s. 3d. per gallon. This works out at ⅕d. per hour, or about 5 hours of 40 candle-power light for 1d.

With a double chimney the lamp gave a 58 candle-power light for one hour on 2 ozs. of the same spirit at the same price, showing cost at between ⅓d. and ¼d. per hour; this latter test giving 3·7 hours of 58 candle-power light for 1d.

Yet another form of portable incandescent lamp utilising petroleum is the Lucisca lamp of Messrs. Falk, Stadelmann and Co.

I cannot here dwell on other types of oil lamps, of which there are many more to be found in the market.

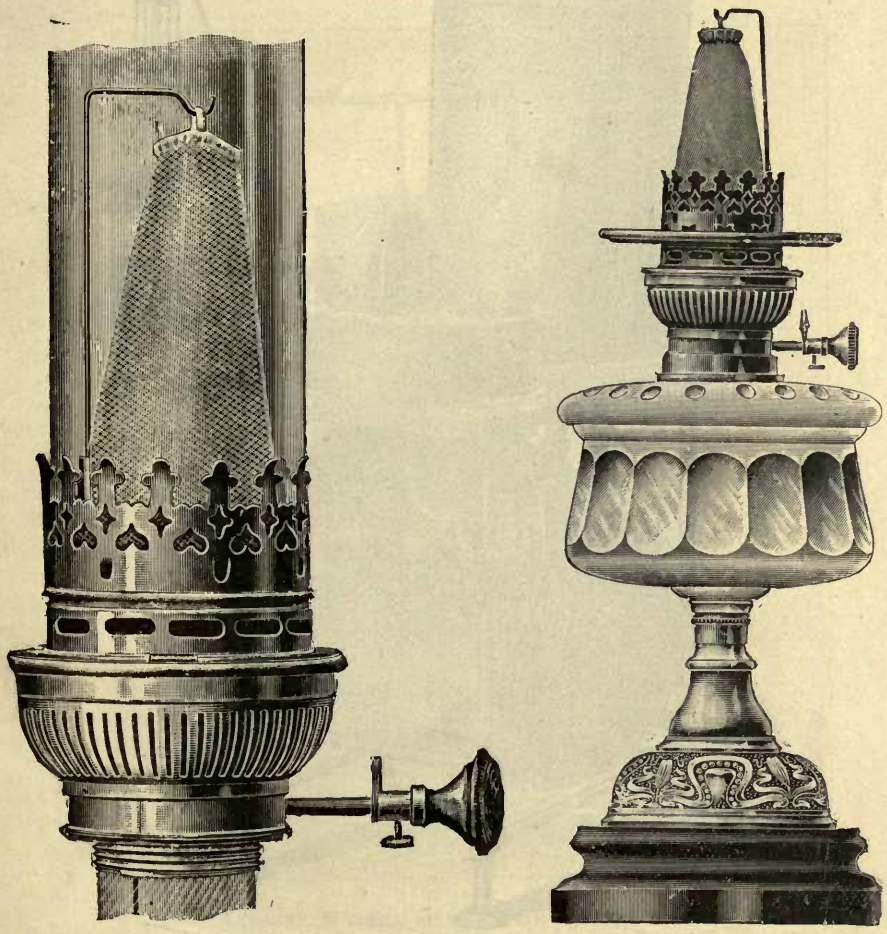
Petrol-Air Gas Lighting.

A considerable amount of interest has been aroused in what are known as "Petrol-Air Systems." They all depend on the generation of a mixture of petrol vapour with air in definite proportions, the air being passed through suitable vessels and carburetted with the illuminating gas. The actual details of the apparatus by which this is achieved vary considerably. Briefly, however, the main essential quality of all is that the mixture generated at the burner should contain a small proportion of petroleum vapour mixed with air, and that the composition of this mixture should be automatically maintained constant. The machine by which this is accomplished usually consists of a small

hot-air engine, operated by the gas it produces, together with a suitable blower, carburetter, and gas-holder; in some cases the motive power is supplied by a falling weight, which is newly wound up from time to time, or, where available, water power.

Such machines are designed with a view to being as easily controlled and as automatic as possible; once the engine is started, quality of gas did not remain constant, so that the illuminating value of the lights was reduced, and they tended to smoke, &c., unless readjusted. The best modern systems, however, claim to have completely avoided this difficulty by suitable design of the plant. In this connection I may refer to a discussion on the point which has recently been taking place in the columns of the *Illuminating Engineer*

FIG. 48.



LUCISCA LAMP. (General View.)

which should only take a few minutes, the apparatus, it is claimed, ought to continue its functions automatically.

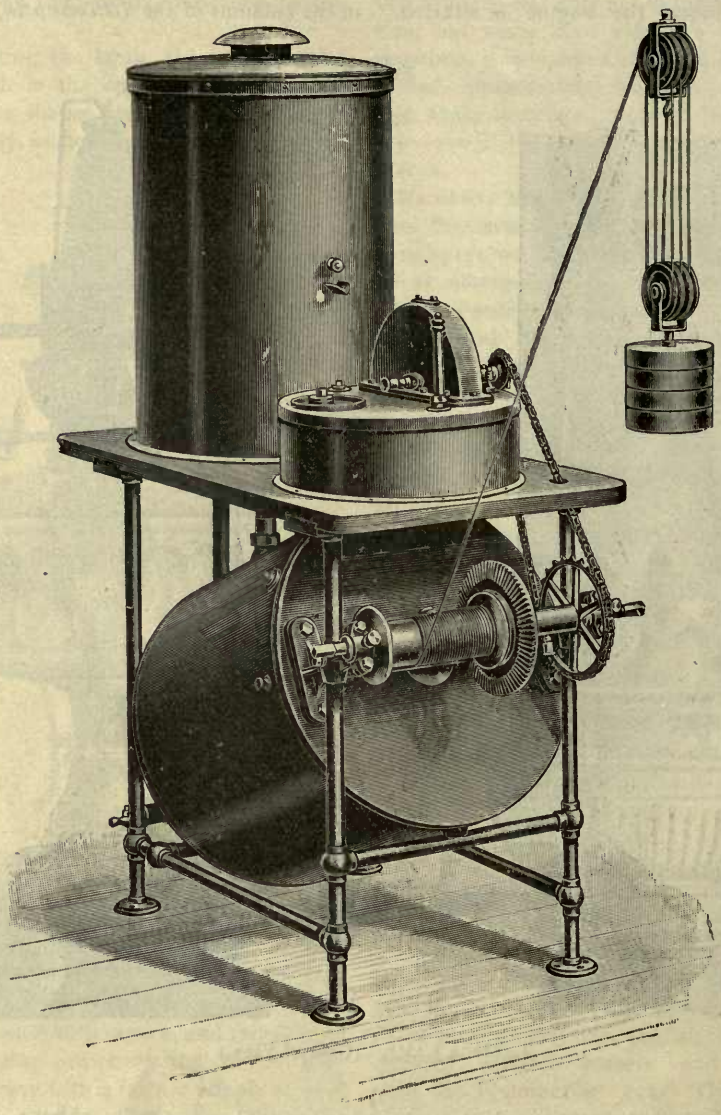
One difficulty against which the system had to contend in the past was the condensation of liquid in the pipes in cold weather. In addition, in defective systems, it was found that, as the burners were turned on and off, and the load on the machine varied, the (August, 1909, pp. 549 and 561 to 568), in which several prominent experts connected with petrol-air lighting took part. All contended, however, that these defects were not to be found in the best modern plants.

Naturally in the time at my disposal I can only refer to a few examples which are representative of this method of lighting. By the kindness of the makers, complete working

plants of the Aerogen, the Machine Gas Syndicate (Cox's system), and National Air-Gas Company's types are on exhibition. In addition to those exhibited on this occasion, which I now propose to describe, I may mention the

vapour per cubic foot of air constant. The petrol-feed and the air compressor work in unison, so that the proportions of petrol and air never vary. The carburation and compression are effected simultaneously in the

FIG. 49.



AEROGEN WEIGHT-DRIVEN PETROL-AIR GAS PLANT.

De Laitte, Praed, Litz, Mitchellite, and Loco systems, which, however, do not by any means exhaust the types available.

Aerogen Gas (Messrs. Strode and Co.).—Aerogen gas is claimed to be a perfectly uniform mixture, the machine being constructed to keep the percentage of hydrogen

same chamber, and an even temperature is maintained in the generating chamber by means of the water contained therein.

The petrol is lifted from the petrol chamber and discharged into the carburetting chamber as required, so that there is no possibility of its being flooded by an excess of petrol. A

small gasholder is provided which serves as an antifluctuator and maintains a uniform pressure.

The whole mechanism is self-controlled. The machine works quickly when the maximum output is required, and slowly when little gas is used, and stops automatically when no more gas is required. The gas mixture consists of 95 per cent. of atmospheric air and 5 per cent. of petrol vapour, this percentage being maintained automatically by the mechanism under all conditions.

As advantages of the method it is claimed that (1) the gas has a high illuminating power, thus enabling the gas consumption to be small; (2) small sized pipes can be used to convey the gas to the burners; (3) additional air being drawn in by the burners during combustion has a cooling effect on the burner, thus maintaining a longer life for the mantles and burners than can be obtained with gas of a poorer quality; and (4) owing to the small amount of gas consumed the consumption at the burners is silent.

With the motor-driven apparatus a specially constructed gas-meter is provided through which the gas passes. This meter records the amount of gas used and controls the petrol feed. When all lights are turned out the production of gas is regulated to keep the motor running only.

The makers state that aerogen gas can be stored in any quantity, and is not liable to condensation. When storage holders are used for country house lighting, an automatic valve is provided so that when the general lights are turned out the holder is fully charged, and the gas supply to the motor automatically turned off, stopping the working of the apparatus, and leaving the storage holder

FIG. 50.

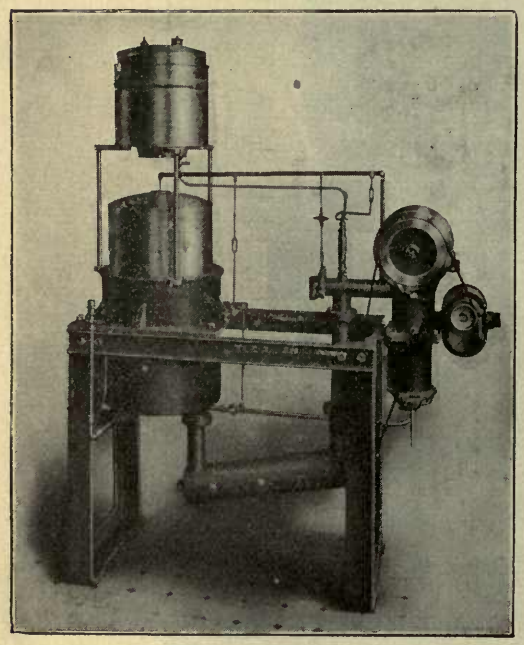
AEROGEN WATER-DRIVEN PETROL-AIR GAS PLANT.

to supply any lights required during the night or in the morning, without the necessity of running the engine.

With the weight-driven machine the light is always available, so that there is no necessity for a storage holder, and economy is effected by dispensing with the motor, thus saving consumption of gas to drive the motor. The weights can be supported from a side wall, or suspended over a disused well, the required drop being from 25 to 30 feet. A steel gantry can be provided to carry the weight where a wall or well cannot be made use of.

It is further stated that the gas can be transmitted for long distances, installations being in use where the gas is transmitted a distance of over eight miles.

FIG. 51.



AUTOMATIC PETROL-AIR PLANT. (Cox's System.)

Aerogen gas has a specific weight of 1·2 compared with air. Its odour is not unpleasant, but is distinctly perceptible in cases of escape. One gallon of petrol is said by the makers to produce 520 cubic feet of gas, and three cubic feet of gas, used with an incandescent mantle, to yield an illuminating power of 40 candle-power.

A general view of the weight-driven and water-driven plants will be obtained in Figs. 49 and 50.

Cox's Air Gas System (The Machine Gas Syndicate, Ltd.).—The demonstration given of this method is mainly intended to show the absence of condensation. The main outlet of the machine, Fig. 51 (No. 12 in Fig. 52), is connected on to a coil, which is immersed in ice and salt, and kept at 15° C below zero the whole time during the lecture; nevertheless it will be seen that the light appears to be unaffected. Cocks are fitted in the coil at various bends, and anyone can satisfy himself by opening one of them that no liquid has collected.

The machine, as illustrated in section, may be briefly described as follows:—The petrol-container is at the top and numbered 8 and 9, the inner vessel containing the petrol, and the outer one water for sealing the floating bell, 9. The safety of this arrangement is claimed to lie in the fact that there is no possibility of the container bursting, the bell 9 following the displacement of petrol as it is used in the machine. After starting the machine, petrol cock 23 is turned on full and feeds through pipe 22 to valve 21, which is controlled by levers 30 and 20, lever 20 being controlled by the position of holder; the petrol passing valve 21 is conveyed down pipe 28 and drips on to grid 3 which rotates; this grid is so constructed that each drop of petrol is spread into a thin film. When started the hot-air motor drives blower 13; the air is drawn in at the inlet, passed round the jacket of hot air engine, and along casting 1, through the grid in the carburettor. In this process it collects all the vapour and evaporates the films found on the grid, and passes up through pipe 4, through valve 5 into the gas holder. The amount used or drawn from the holder 7 determines the position of this holder, which in turn controls the delivery of petrol and air to the carburettor by means of the connections, 20, 24 and 25. (See Fig. 52.)

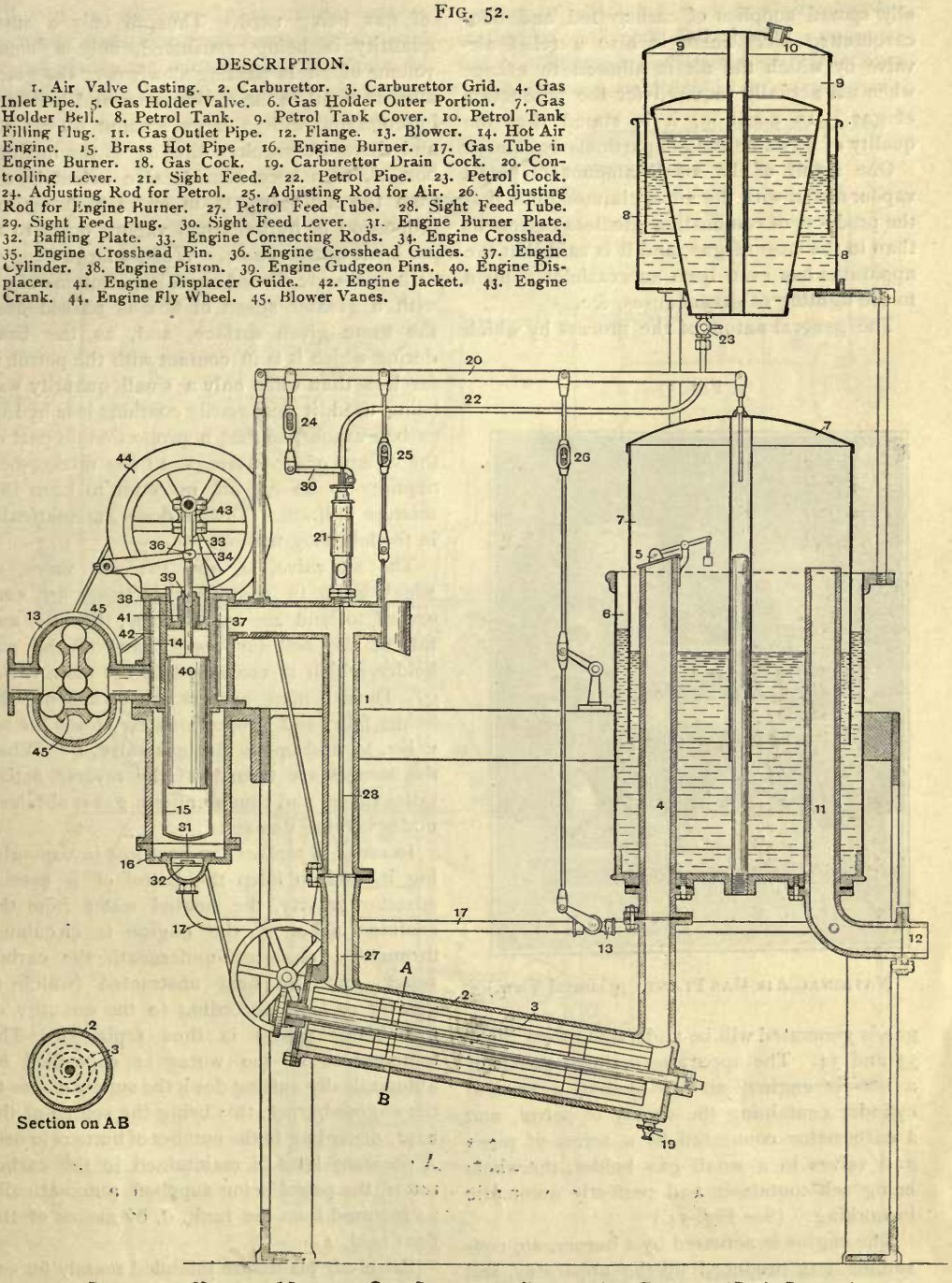
This machine is claimed by the makers to be very simple in operation, and within the understanding of almost anyone, care being only required in keeping it clean and lubricating. In addition it is stated that the machines have been found to work quite satisfactorily under very varied climatic conditions.

National Air-Gas System.—An illustration of this method of petrol-air gas lighting is afforded by the apparatus which, by the kindness of the makers, I am privileged to be able to show you this evening. This method utilises also about 1½ per cent. of petrol vapour, and it is stated that 1,600 cubic feet of gas are produced per gallon of petrol costing 6d. The essential details of the method are connected with the method of obtaining a uniform gas from the carburettor,

FIG. 52.

DESCRIPTION.

1. Air Valve Casting. 2. Carburettor. 3. Carburettor Grid. 4. Gas Inlet Pipe. 5. Gas Holder Valve. 6. Gas Holder Outer Portion. 7. Gas Holder Bell. 8. Petrol Tank. 9. Petrol Tank Cover. 10. Petrol Tank Filling Plug. 11. Gas Outlet Pipe. 12. Flange. 13. Blower. 14. Hot Air Engine. 15. Brass Hot Pipe 16. Engine Burner. 17. Gas Tube in Engine Burner. 18. Gas Cock. 19. Carburettor Drain Cock. 20. Controlling Lever. 21. Sight Feed. 22. Petrol Pipe. 23. Petrol Cock. 24. Adjusting Rod for Petrol. 25. Adjusting Rod for Air. 26. Adjusting Rod for Engine Burner. 27. Petrol Feed Tube. 28. Sight Feed Tube. 29. Sight Feed Plug. 30. Sight Feed Lever. 31. Engine Burner Plate. 32. Baffling Plate. 33. Engine Connecting Rods. 34. Engine Crosshead. 35. Engine Crosshead Pin. 36. Engine Crosshead Guides. 37. Engine Cylinder. 38. Engine Piston. 39. Engine Gudgeon Pins. 40. Engine Displacer. 41. Engine Displacer Guide. 42. Engine Jacket. 43. Engine Crank. 44. Engine Fly Wheel. 45. Blower Vanes.



SECTIONAL VIEW OF MACHINE GAS SYNDICATE PETROL AIR-PLANT. (Cox's System.)

where the air is charged with petrol vapour. This uniformity must, of course, be maintained, even though the differences in the flow and volume of the air passed through are very great, and there are considerable fluctuations in temperature.

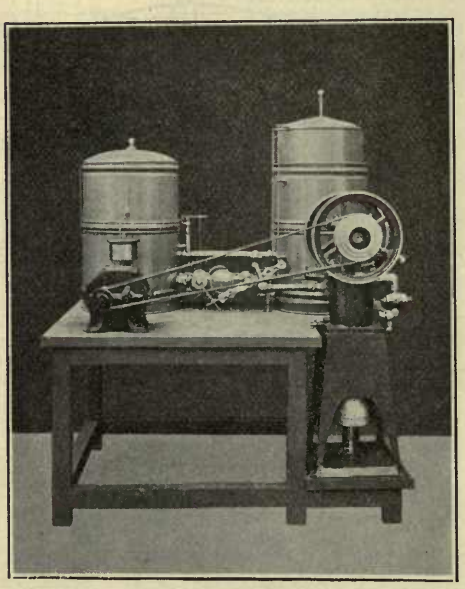
In this method a hot-air engine and air blower are utilised in order to generate the gas, and special arrangements are necessary in order to control the admission of air. This is now accomplished by a thermostatic control, which is arranged to admit automatic-

ally spread supplies of carburetted and non-carburetted air. There is also a relief air-valve by which the air is allowed to escape when not actually required for the production of gas. In addition, it is stated that the quality of gasoline used is particularly safe.

One result of the small amount of petrol vapour mixed with the air is claimed to be that the products of combustion are less poisonous than in the case of gas, and it is said that the apparatus has even been successfully applied to the lighting of greenhouses, &c.

The general nature of the process by which gas is generated will be understood from Figs. 53 and 54. The apparatus mainly consists of a hot-air engine, an air blower, a vertical cylinder containing the supply of petrol, and a carburettor connected by a series of pipes and valves to a small gas holder, the whole being self-contained and perfectly automatic in working. (See Fig. 54.)

FIG. 53.



NATIONAL AIR-GAS PLANT. (General View.)

The engine is actuated by a burner, 20, consuming gas produced by the apparatus, and this drives the blower, I. After leaving the blower the air is divided into two streams, the right hand supply passing to the valve, M; the supply on the left flows direct to the carburettor, in its passage through which it is caused to impinge on the surface of the petrol and becomes impregnated with proportionately more or less vapour, according to the amount of gas being used. Thus, if only a small quantity is being consumed, only a small volume of air is passing slowly over the given surface of oil in the carburettor, and becomes impregnated with a large amount of vapour, and therefore requires diluting in the mixing-box, N, to a very considerable extent by air from the air valve, M, in order to bring the proportion of hydrocarbon vapour down to 1¼ per cent. of the whole. When a large number of burners are turned on, a large volume of air with a greater speed of flow is passed over the same given surface, and, as the time during which it is in contact with the petrol is far less than when only a small quantity was being used, it necessarily contains less hydrocarbon vapour, so that a proportionate part of the volume of air passing into the mixing-box requires to be cut off in order to keep the mixture uniform. This is done automatically in the following manner:—

The air valve, M, and the gas valve, O, which work in contrary directions, are connected to, and are operated by, the rise and fall of the bell (or upper part) of the gas holder, which is controlled by the main valve, Q. Thus, if more burners are turned on, the holder falls, and proportionately closes the air valve, M, and opens the gas valve, O. When the burners are turned off the reverse action takes place, and thus a uniform gas is obtained under varying demands.

In order to replace the heat lost in vapourising it, and to keep the petrol of a normal specific gravity, the heated water from the cooling jacket of the engine is circulated through a chamber underneath the carburettor, and the heat abstracted (which is greater or less, according to the quantity of gas being made) is thus replaced. The temperature of the water is controlled by automatically cutting down the supply of gas to the engine burner, this being the source of the heat, according to the number of burners in use. A constant level is maintained in the carburettor, the petrol being supplied automatically as required from the tank, C, by means of the float feed, A.

Petrol-air plants are intended mainly for use in remote country districts, &c., where gas or electricity is not available. However, an interesting development seems to have been recently recorded in Romford, where a number of adjacently situated shop-keepers propose to co-operate and erect a common air-gas generator, anticipating that the result will be cheaper than the local gas supply.

But it is still mainly in districts where electricity and gas are not available that petrol air-gas plants are particularly acceptable, for example, in the lighting of country residences.

gineer, to which reference has already been made (August, 1909), and also in a paper by Mr. C. Bingham and some correspondence which followed, published in the same journal

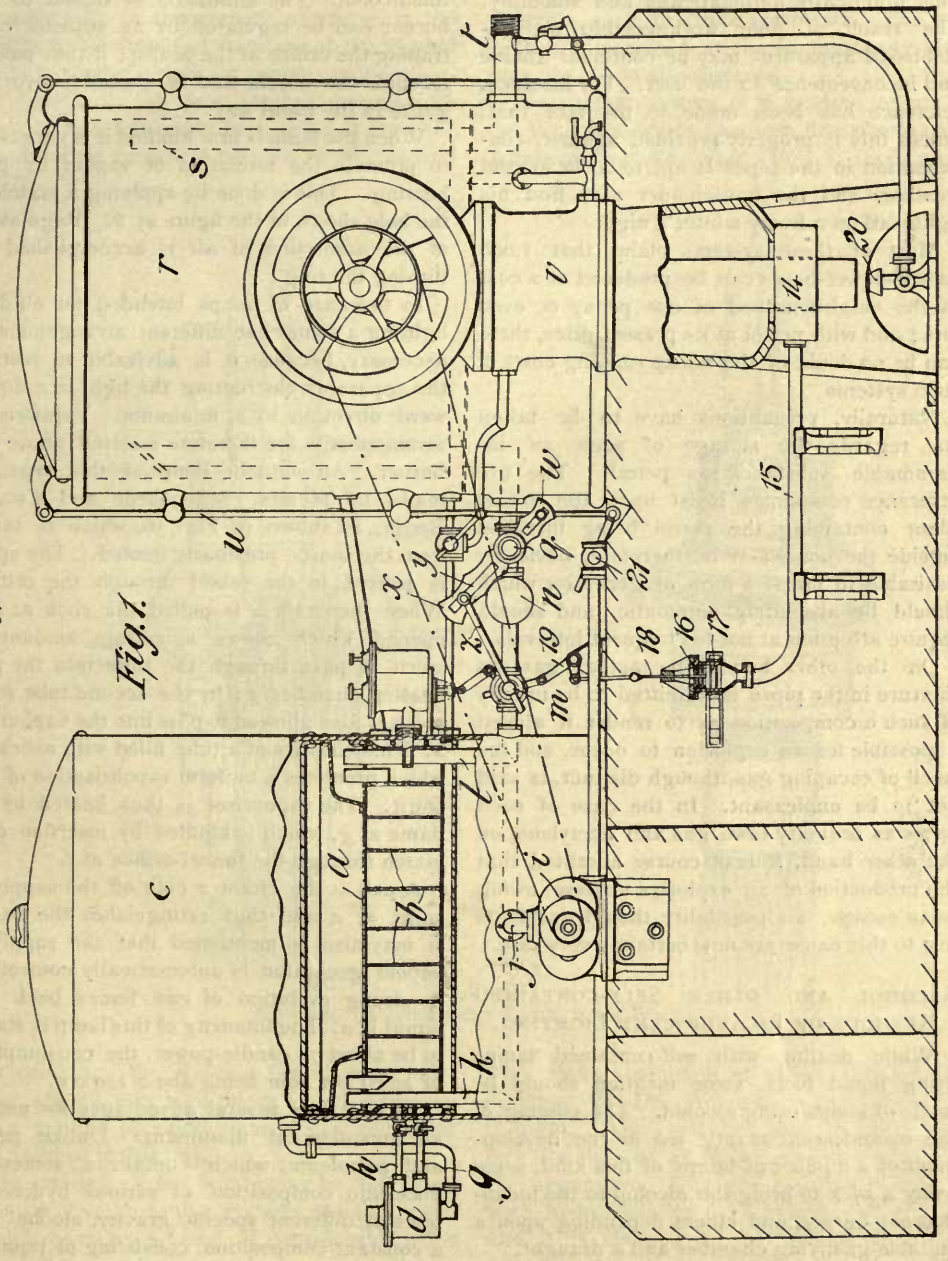


Fig. 54.

This is a field for which acetylene has also great merits, and there is, therefore, naturally some competition between these two illuminants. A *résumé* of the merits of both methods, may be found in the recent communications to the *Illuminating En-*

on the previous year (Vol. I., 1908, p. 547).

One thing may be said with certainty, however. A consumer who contemplates installing a plant of this kind would do well to go to a thoroughly reliable firm, and ensure that he

receives the best workmanship available. With a plant of this kind, the daily running of which depends upon his own exertions, success is only attained when the arrangement runs practically automatically and smoothly. The result of poor workmanship or old-fashioned apparatus may be continual trouble and inconvenience to the user. For instance, reference has been made to the fact that, unless this is properly provided against, condensation in the pipes is apt to occur in cold weather, and the householder may find his lights fail on a frosty winter's night.

Most of these systems claim that 1,000 candle-power-hours can be produced at a cost in the neighbourhood of one penny or even less; and with petrol at its present price, there can be no doubt of the cheap running costs of such systems.

Naturally, precautions have to be taken as regards the storage of such an inflammable substance as petrol. The fire insurance companies insist upon the actual plant containing the petrol being installed outside the house; it is, therefore, obviously desirable to utilise a form of generator which should be absolutely automatic, and should require attention at not too frequent intervals.

On the other hand, the actual gaseous mixture in the pipes is admitted to be usually of such a composition as to render it almost impossible for an explosion to occur, and the smell of escaping gas, though distinct, is said not to be unpleasant. In the case of such gases as ordinary town gas and acetylene, on the other hand, it is of course admitted that the production of an explosive mixture, owing to an escape, is a possibility, though accidents due to this cause are now certainly very rare.

Alcohol and other Self-contained Methods of Incandescent Lighting.

While dealing with self-contained lamps using liquid fuels, some mention should be made of lamps using alcohol. The coming of the incandescent mantle led to the development of a number of lamps of this kind, some using a wick to bring the alcohol to the incandescent burner, and others depending upon a suitable gasifying chamber and a draught.

Fig. 55 shows an illustration of a spirit lamp of the wick type which is taken from an interesting little book on this subject recently published in Germany (W. Brüsch, "Die Beleuchtungsarten der Gegenwart"). The support of the incandescent mantle in this case consists of copper, brass, or any good conducting metal. It is arranged to bend round the burner nozzle and partially to encircle the wick tube. In this way a portion of the heat of the flame can be communicated to the alcohol. The admission of vapour to the burner can be regulated by an adjuster controlling the orifice at the nozzle; it thus passes through the nozzle and is ignited above the gauze in the usual way.

When the lamp is first kindled it is necessary to promote the formation of vapour by preheating. This is done by applying a match at the hole shown in the figure at *b*. Regulation of the admission of air is accomplished by turning the ring *c*.

In the case of lamps intended for outdoor lighting a somewhat different arrangement is necessary, because it is advisable to restrict the apparatus obstructing the light in a downward direction to a minimum. Vapourising arrangements are therefore inserted above the burner. An outdoor lamp of this type, as made by Messrs. Schuchardt and Co., of Berlin, is shown in Fig. 56, which is taken from the source previously quoted. The spirit is poured in the vessel through the orifice. When the chain *o* is pulled the cock at *h* is opened, which allows a certain amount of spirit to pass through the tube into the preheating chamber *g*; by the second tube *k* the spirit is also allowed to pass into the vapouriser *a*. This consists of a tube filled with asbestos, which promotes a uniform vapourisation of the spirit. The vapouriser is thus heated by the flame at *g*, which is kindled by insertion of a match through the funnel-orifice at *l*.

A pull at the chain *z* cuts off the supply of spirit at *a* and thus extinguishes the flame. It may also be mentioned that the supply of vapour generated is automatically controlled. A strong evolution of gas forces back the liquid in *a*. The intensity of this lamp is stated to be about 75 candle-power, the consumption of spirit per hour being about 140 c.c.

Alcohol has several advantages for use as an incandescent illuminant. Unlike petrol and petroleum, which contain a somewhat uncertain composition of various hydro-carbons of different specific gravity, alcohol has a constant composition, consisting of liquid of the formula C_2H_5OH. This theoretically should make it easier to produce a perfect type of burner, and complete combustion. In addition, while alcohol is admittedly not a very inflammable liquid, and will not easily vapourise, it has also the property of mixing with water, and is, therefore, readily extin-

guished by a water douche. In many countries, again, there is no natural oil supply, but on the other hand, the agricultural possibilities of the locality make it an easy matter to secure a supply of alcohol for illumination. One difficulty in this respect, of course, is the question of suitable adulteration of the alcohol so as to render it unfit for human consumption. In Russia, in the past, alcohol intended for burning has frequently been purified from the adulterating constituents, and afterwards sold for drinking; the Russian Government, however, offered very high prizes for the discovery of a method of adulteration which could not be nullified in this way.

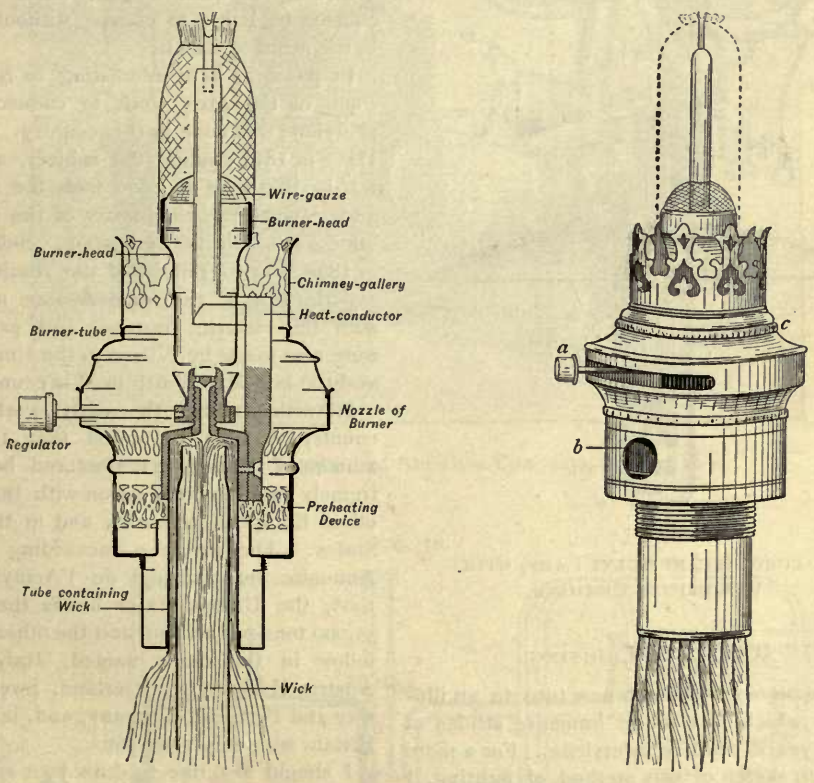
In passing, a few words may be said about the use of various other systems of liquid fuels, which have been found of considerable value for lighting railway carriages, &c., and in other cases where portability is extremely desirable. In these systems various hydrocarbons are frequently liquefied under considerable pressure, stored in cylinders, and may then be carried about at any particular destination. One of the oldest systems in this country is the Pintsch oil gas system in which oil gas is subjected to a pressure of 6 to 7 atmospheres per square inch.

The Blaugas again is a special liquid illuminating gas produced by distillation of minerals, such as crude petroleum. The gas is then compressed at the exceptionally high pressure of 100 atmospheres.

Yet another system of a kindred nature is the Wolf gas, which has been described in the *Illuminating Engineer* (Vol. I, 1908, page 681), and a specimen of which, through the kindness of Dr. Achner, is on exhibition to-night. You will be able to form your own conclusions as to the compact nature of the apparatus. This gas consists mainly of such hydro-carbons as ethylene and ethane, and it is claimed to be influenced to an exceptionally small extent by external temperature.

Most of these gases have been rendered much more useful by the coming of the incandescent mantle, for some of them are credited with an exceptionally high calorific value; this leads to a high efficiency in the

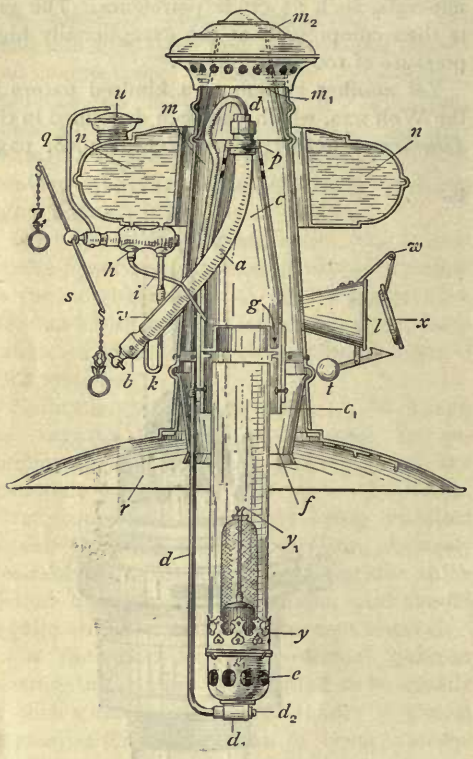
FIG. 55.



ALCOHOL INCANDESCENT LAMP, WITH WICK.

burner, Wolf gas being credited with about 60 to 70 English candle-power per cubic foot of gas consumed per hour.

FIG. 56.



ALCOHOL INCANDESCENT LAMP, WITH VAPOURISING CHAMBER.

ACETYLENE LIGHTING.

Introduction.—I must now turn to an illuminant which has made immense strides of recent years, namely, acetylene. For a more complete sketch of this method of lighting, I must refer you to the well-known Cantor lectures of Professor Vivian Lewes on the subject.

Acetylene lighting has only been developed to perfection by dogged perseverance, and many were the difficulties which early workers in the field had to contend against. For instance, acetylene itself seems to be an especially sensitive gas which it was difficult, at one time, to procure in a state of purity, and which tended to form "polymerides," possessing undesirable qualities, such as unpleasant odour, and explosive tendencies.

In addition, impurities such as phosphone rendered the gas liable to spontaneous combustion, and were also said to be responsible for the slight haze which used, at one time, to accompany the burning of acetylene in a room. Again, a mixture of seven of air to one of acetylene is very explosive. Nowadays, however, very careful purification has removed many of these defects, and attention to keeping the generator cool, and other matters, has prevented the tendency to polymerise to a great extent. To-day it is possible to burn acetylene without much smell, and it is said that the gas itself could be rendered absolutely odourless were it not for the danger attaching to such a gas, which would, of course, be liable to escape without detection in the event of a leak.

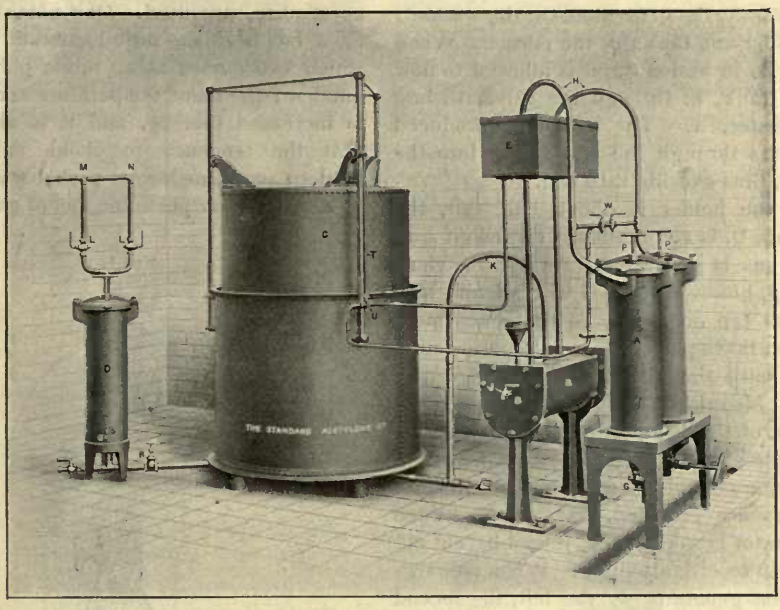
In passing, it is interesting to recall that some of the early work in connection with acetylene was done in this country. Humphry Davy in 1836 studied the subject, and afterwards Berthelot in 1866 took the matter up and showed the complexity of the re-actions taking place in its combustion. Subsequently in 1892 Moissan published the results of some experiments of the manufacture of carbide with the electric furnace, and experiments were also made by Wilson in the United States and the late Mr. Worth in this country.

Notwithstanding the early work in this country it may be noted that the actual amount of carbide manufactured here is extremely small in comparison with that in most other European countries and in the United States. For instance, according to "The Annuaire International de l'Acétylène" for 1908, the United States heads the list with 35,000 tons per annum, and the other countries follow in the order named, Italy, France, Austria-Hungary, Switzerland, Sweden, Norway and Portugal, Germany, and, lastly, Great Britain with only 1,000 tons.

I should also like to draw your attention to the striking example of the co-operation between those interested in different branches of science that the production of acetylene affords. The hydraulic engineer is interested in the water-power which is almost invariably used for carbide manufacture, the chemist and physicist are interested in the problem of its manufacture and combustion, and the illuminating engineer finally is interested in the use of the light obtained. Curiously, too, it is from water that the power to manufacture carbide is obtained, and it is with water that this carbide gives off acetylene gas; the person carrying a tin of carbide in his pocket can be said, in a very literal sense, to be carrying bottled-up natural energy.

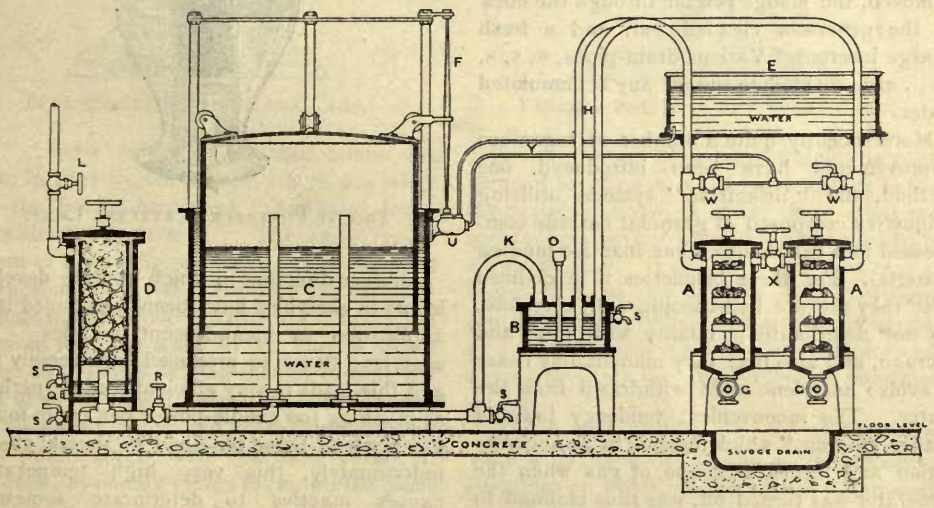
Generating Apparatus.—The development of the generators themselves does not fall strictly within the scope of my lecture. It was at one time the subject of discussion whether the carbide should be allowed to fall into water, or whether water should be allowed to drop on to the carbide. At the present day both methods are employed, and there are varieties of apparatus which show a gradual gradation from one type to the other. In the "Annuaire International de l'Acétylène," an interesting compilation of information relating to this method of lighting for 1908, some account is given of the different types of generating apparatus in use in France and other countries. In France and Italy methods depending on the dropping of water on to carbide prevail, while in Switzerland and Holland, on

FIG. 57.



ACETYLENE PLANT (the Standard Acetylene Company), General View.

FIG. 58.



the other hand, the carbide to water system is predominant.

The general nature of a modern automatic generating plant will be understood from Figs. 57 and 58, which illustrate that exhibited this evening by the Standard Acetylene Co. The principal parts of the plant are as follows :—A, the generator ; B, the washer ; C, the holder and tank ; D, the purifier. When the plant is in action water is allowed to flow from the tank, E, through the valve, U, into the generator, A. The acetylene produced then passes through the washer, B, into the bell, at C, thus causing it to rise.

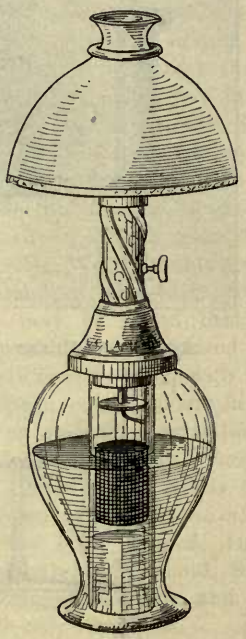
When the holder is about half full, the control tap, U, is automatically turned off and no more gas is generated. As the acetylene is used up, however, the bell will fall and turn the control tap on again, so that once more generation takes place. This automatic action goes on until the charge of carbide is exhausted. Meanwhile the gas used for burning passes out of the holder through the purifier, D, on to the burner.

One feature of this plant is that two distinct generators are provided, as shown. When one generator is worked out it can be cut out of action to receive attention. When recharging the first generator on the left, the second tap, W, would be opened so that the water could pass into the second generator on the right, and the first tap, W, is closed. The cover of the first generator may then be removed, the sludge run off through the cock G, the generator cleaned out, and a fresh charge inserted. Various drain-pipes, S, S, S, ... are provided to run off any accumulated water.

More recently quite a number of ingenious improvements have been introduced, one method, the "Brikettide" system, utilising briquettes composed of granular carbide compressed into cakes with some inactive binding material. For these briquettes it is claimed that they are not hydroscopic and, therefore, do not deteriorate in quality with time and storage, and also that they immediately cease to evolve acetylene when withdrawn from the water. The inconvenient tendency towards "after-gassing," which resulted in the accumulation and ultimate escape of gas when the generator was turned off, was thus claimed to be avoided. Similar efforts in this direction had previously been made. For instance, the carbide was compressed into cakes and coated with paraffin or sugar.

Acetylene Burners.—The design of the acetylene burners has recently been improved to such an extent as to remove many of the early troubles to a great extent and notably in the direction of avoiding their tendency to become choked up. One cause for this habit of early burners was the fact that metal was used. Nowadays, refractory materials, such as steatite, are used. One notable improvement has been the introduction of a burner in which two flames at an angle play upon one another ; the flame temperature and efficiency is increased thereby, and it is also claimed that the tendency to choke is less. The modern acetylene burner probably yields about 30 candle-power per cubic foot of gas per hour.

FIG. 59.



TROUVÉ PORTABLE ACETYLENE LAMP.

Another direction in which notable developments in acetylene have been introduced is its application to incandescent mantles. The acetylene flame so produced is extremely hot, and this leads to very efficient results, perhaps as much as 100 candle-power per cubic foot of gas per hour being obtained in special cases ; unfortunately, this very high temperature causes mantles to deteriorate somewhat rapidly, and it has been found necessary to make them exceptionally small and stout. It has been claimed that the Hella Bushlight, of which we have an example on exhibition, is specially suitable for the acetylene flame, as

the refractory needles of which it is composed are able to stand the temperature better; the durable nature of this mantle is also said to render it particularly serviceable for portable lights, for which liquid fuels are, of course, specially intended.

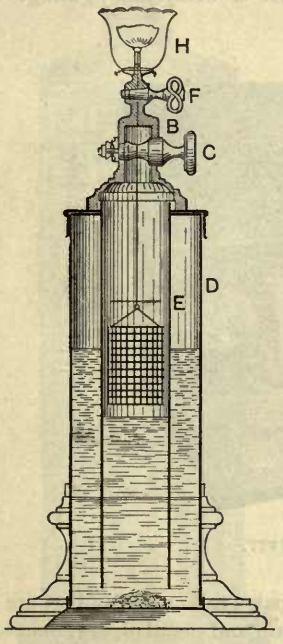
Portable Acetylene Lights. — Portable acetylene lights are of comparatively early origin. The chief difficulties experienced have been connected with the regulation of the pressure and the provision of means of checking surplus evolutions of gas and 'after-gassing.'' Some forms of portable lamps are shown in Figs 59, 60, and 61, which are taken from the before-mentioned "Annuaire Internationale de l'Acétylène." The early Trouvé pattern of lamp (Fig. 59) could not be regarded as practical to-day as there were not adequate methods to check over-production of gas. An improved form lamp due to M. Türr is shown in Fig. 60. It will be seen that by turning the knob at C the vessel containing carbide at E can be raised or lowered in the surrounding water which enters from the outer vessel, D. The cock, F, merely serves to control the flame at H.

In the Cerckel lamp shown in Fig. 61, again, the water in the reservoir, A, is allowed to fall through the pipe, T, at intervals, so as to flood the carbide within the vessel at B, compartment by compartment. When the level at C is reached, the charge needs renewal.

Many other forms of improved lamps have been introduced equipped with very ingenious devices to control the evolution of gas. Portable lamps have, of course, found a great application for cycles and automobiles; the first lamp of this kind is stated, in the above mentioned periodical, to have been introduced by M. Itier, about 1898. They have also been applied with success to the lighting of mines and collieries. One advantage which they are claimed to possess in this connection is that the acetylene flame is stiffer than an oil one, and is therefore not so readily extinguished by a gust of wind. It is also pointed out that an acetylene flame, for a given amount of light, consumes a relatively small amount of oxygen as compared with oil, and therefore does not so readily vitiate the atmosphere in restricted spaces.

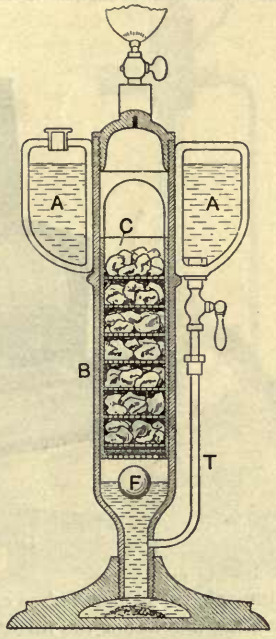
Dissolved Acetylene.—I may next refer to what is perhaps one of the most interesting directions in which acetylene has progressed, namely, its preparation in a liquid condition. The convenience of dissolved acetylene was early realised, but there were many initial difficulties to overcome, and not a few serious explosions. Dissolved acetylene, however, can

FIG. 60.



TÜRR PORTABLE ACETYLENE LAMP.

FIG. 61.



CERCKEL PORTABLE ACETYLENE LAMP.

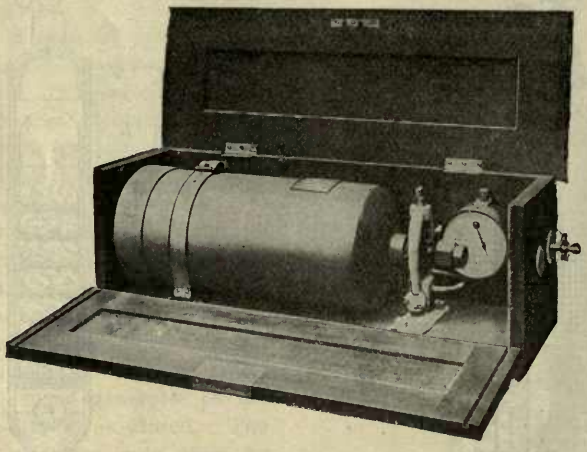
be utilised to-day under a pressure of ten atmospheres if certain directions are observed, including the insertion of some suitable porous substance into the containing vessel. (Fig. 62.)

More recently a much greater development has been achieved through the use of the comparatively cheap liquid acetone, which possesses the remarkable property of dissolving about 240 times its own volume of acetylene at a pressure of 10 atmospheres, and a temperature of 15 degrees. Such a vessel of acetone saturated with acetylene gas at this pressure will, therefore, liberate 215 times its own volume when the pressure is reduced to

market place in a small town, to invest in an acetylene installation. In country railway stations again acetylene installations have been found to have a great field.

Like petrol-air lighting, acetylene also commends itself for the lighting of country residences. But here, again, the point should be emphasised that it is very essential to secure good workmanship. In the case of acetylene lighting it is particularly desirable that all piping should be properly laid and all joints absolutely gas-tight; consumers may be advised to have work of this kind undertaken by a specialist in acetylene lighting. It is far

FIG. 62.



DISSOLVED ACETYLENE OUTFIT.

ordinary atmospheric value. Tubes of one litre capacity, containing about 100 litres of acetylene have been proved to be of very great value where portability is the chief consideration.

Special Uses of Acetylene.—It may next be desirable to say a little on the special circumstances under which acetylene lighting is particularly satisfactory. Like the other systems with which we have been dealing, acetylene lighting is essentially a self-contained portable system, and mainly comes into use where electricity and gas are not available. It may indeed be said to fill positions very similar to those for which petrol air-gas is intended, so that the competition between these two systems of illumination is naturally somewhat keen.

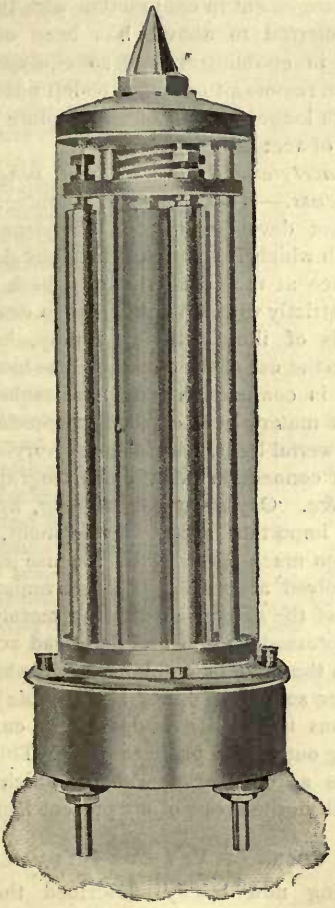
In addition, acetylene may be said to represent all stages of portability, from the generator down to the tube filled with liquid acetylene. For instance, in France and Germany it is not uncommon for a small town, or even the

better to pay a little more and secure a reliable form of plant and sound piping, than to invest in a cheap installation which is a constant source of trouble and annoyance. Many reputable firms are willing to enter into an agreement to execute free any repairs which occur within a given period after installation, thus making themselves responsible for the plant being in good order.

There are, however, many other cases in which dissolved acetylene is particularly serviceable. For instance, when it was necessary to instal a generator on a railway train, the bulk taken up by the apparatus was a considerable disadvantage. More recently, however, liquid acetylene seems to have proved very convenient on quick trains. All that is necessary is to instal the cylinder and connect up to the pipe; at the end of a series of journeys, when the cylinder has been nearly exhausted, it is handed over to be re-charged and replaced by a new one. There are on record

many instances of railway trains having maintained their lighting for many hours in an emergency. For instance, a train lighted by dissolved acetylene, which was blocked in a snowdrift in America, was once able to supply light without interruption for twelve days on end, and it is stated that in many of the carriages of the American Lackawanna Railway Company, cylinders only need re-charging every two months. Another field in which

FIG. 63.



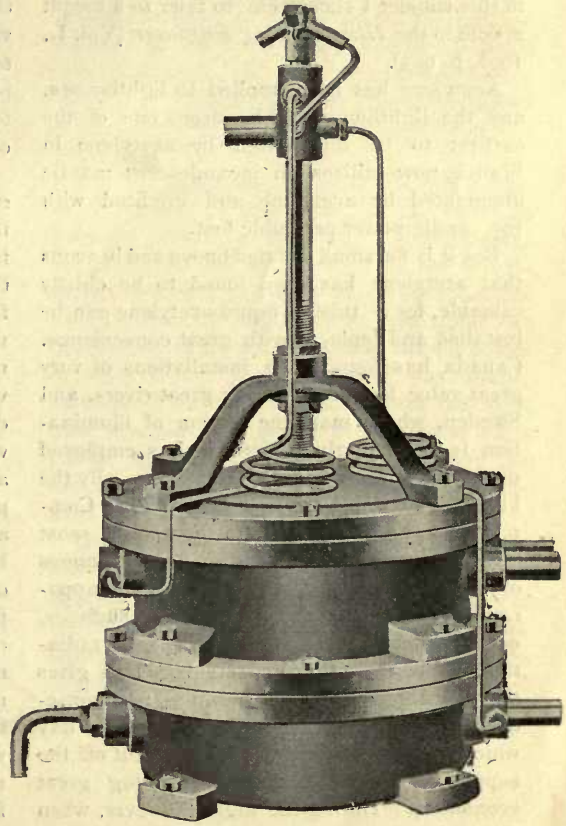
DALEN SOLAR VALVE, which automatically cuts off the main supply of Acetylene in Daylight.

liquid acetylene might be expected to play a useful part is for omnibus and tramcar lighting, and I think that the importance and commercial advantage of lighting the inside of these vehicles in a reasonably satisfactory manner, demands the attention of omnibus companies. Again, liquid acetylene has been utilised for emergency lighting on festive occasions in churches.

Naturally acetylene obtained in this way must always be somewhat more expensive than when obtained from a generator, but this is compensated for by the convenience.

The coming of the incandescent mantle, however, has given new life to the application of systems of liquid gas to railway trains. At one time such systems were in danger of being ousted by liquid acetylene, and Professor Vivian Lewes introduced a system

FIG. 64.



DALEN ACETYLENE FLASHLIGHT APPARATUS.

by which methane gas was mixed with acetylene, so that a compromise between the cheapness of the one and the high illumination obtainable from the latter was arrived at; this, however, was in the days of flat flame lighting. At the present day the arrival of inverted mantles capable of standing the vibration of trains has given to ordinary gas a powerful weapon, and the use of liquid gas in this way is not to be despised.

At the same time the introduction of the metallic filament lamps, which are particularly suited to the low voltages that can be em-

ployed on electrically lighted trains has proved a great help to electric lighting. One very real advantage possessed by such lamps is the fact that their installation would diminish the power output necessary from the generator, for a given illumination, by at least one-third.

Acetylene Lighting of Buoys, Beacons, &c.—Lastly, I would like to refer to one field in which liquid acetylene has found a very extensive application indeed, namely, the lighting of buoys and beacons, &c., in inaccessible places. Those who are interested in this subject I should like to refer to a recent article in the *Illuminating Engineer* (Vol. I., 1908, p. 905).

Acetylene has been applied to lighthouses, and the lighthouse at Chassiron, one of the earliest to be illuminated by acetylene in France, now utilises an incandescent mantle illuminated by acetylene and credited with 105 candle-power per cubic foot.

But it is for small isolated buoys and beacons that acetylene has been found to be chiefly valuable, for a tube of liquid acetylene can be installed and replaced with great convenience. Canada has found such installations of very great value for buoys on her great rivers, and Sweden, whose maritime system of illumination is exceedingly important, has employed dissolved acetylene very extensively. By the kindness of the Acetylene Illuminating Company, Limited, I am able to show you a most ingenious automatic device for use with buoys of this character. The working of the apparatus is based upon the action of two surfaces, one of which is black and absorbs solar radiation, while the other reflects it. This gives rise to a difference in temperature, and consequently an unequal expansion during the day which causes a valve to close and cut off the supply of acetylene, thereby effecting great economies. During the night, however, when the sun's rays are absent, the valve is open for the same reason that it closes during the daytime, and the apparatus is thus made completely automatic. Similar devices using the property of the selenium cell, the resistance of which is enormously diminished by the action of light, have also been employed.

Another ingenious automatic device manufactured by the same company—the Dalen apparatus, on exhibition to-night—is arranged to cut off all gas except a bye-pass, and then to re-admit the full flow of gas again at certain regulated intervals. In this way we obtain an automatic flashlight apparatus which is serviceable in two ways. In the first place the flashlight is more serviceable to attract attention in mists, &c., as a fluctuating light is more readily detected than a steady one. In addition it permits a great saving of gas to be accomplished. For instead of burning the light continuously it is now extinguished for certain definite intervals of time and only flashed occasionally. For instance, a flash of a duration of one-third of a second every third second would lead to a saving of 90%. The economy in gas over a long period may therefore be very considerable, and the use of this arrangement in conjunction with the solar valve referred to above, has been of great service in enabling buoys so equipped and placed in remote situations to be left unattended for much longer periods of time before a fresh charge of acetylene is needed.

Oxy-acetylene Welding and other Developments.—There are, of course, other important developments of acetylene lighting with which I cannot deal in any detail in the space at my disposal, and which do not fall so strictly within my province in describing methods of illumination. I may, however, mention the use of the oxy-acetylene blow-pipe, which, in conjunction with a suitable incandescent material, is capable of producing a very powerful light, and is found very serviceable in connection with cinematograph displays, &c. Oxy-acetylene welding, again, is a very important recent development, which has been much assisted by the use of tubes of dissolved acetylene. The convenient simplicity of the apparatus utilising merely tubes of compressed oxygen and dissolved acetylene renders the process specially serviceable when no other source of power is available and in situations in which it is desired to carry the welding outfit from place to place. This, however, is an interesting subject which hardly falls within the scope of my present lecture.

The Costs of Various Illuminants.

Having now briefly described the chief modern systems of illumination, I may, perhaps, be expected to give some account of their relative costs. As I have explained before, I myself do not attach very much value to Tables of this description, partly because of the difficulty in ascertaining the exact conditions under which they were compiled, and also because the results, even if they are obtained on the same basis, will often prove to be misleading if applied to actual practical conditions. I have examined a series of Tables of this kind recently published: in some cases it was impossible to

compare them with any precision owing to the different methods used in expressing the results.

I have, however, brought the costs down to the same basis, and compiled the following Table therefrom, which may perhaps be regarded as representative of average conditions :—

COST OF GAS, OIL, OR ELECTRIC ENERGY ONLY PER 1,000 CANDLE-POWER.—Hours (Electricity 4d. per unit; Gas, 2s. 6d. per 1,000 cubic feet; Carbide, 3d. a lb.; Petrol, 1s. 2d. a gallon; Paraffin, 1s. 7d. a gallon).

	s.	d.
Electric flame arc	0	1
High pressure gas	0	1¼
Incandescent high pressure oil	0	1¼
Petrol air gas	0	1½ to 2
Electric mercury vapour lamps	0	2
Self-intensifying gas lamps	0	2¼
Incandescent mantle (low pressure)	0	3
Alcohol incandescent lamps	0	3
Electric open white arc lamps	0	3
Enclosed arc lamps	0	4
Helion electric glow lamps	0	4
Moore tube (electric)	0	4½
Tungsten electric glow lamp	0	5
Osmium electric glow lamp	0	6
Alternating arc lamp	0	6½
Argand gas burner	0	7
Tantalum electric glow lamp	0	7½
Miniature arc lamp	0	7½
Nernst electric glow lamp	0	7½
Metallised electric glow lamp	0	8½
Oil lamp	0	9
Flat-flame gas burner	0	11
Carbon filament electric glow lamp	1	2½

However, I consider that in reality, though such Tables are very useful (provided that the assumptions are clearly stated), as a means of comparing the efficiency of the source itself, they are certainly rarely reliable in any practical case where it is desirable to obtain a given value of *illumination*. For one thing, it is obviously absurd to compare a 1,000 candle-power unit with a small candle-power glow lamp; light for light the high candle-power source may be of a higher efficiency, but then we rarely wish to instal such a source in an interior of moderate dimensions; and in any case the diffusion of light would probably be so unsatisfactory from a single high candle-power source, that we should prefer a number of small sources, even if less efficient. Naturally too, there are very often many other conditions quite apart from cost which come into the problem.

For instance, the method in which the candle-power is specified in the case of different sources may vary considerably. Electrical sources are usually, but not invariably, expressed in terms of mean spherical candle-power, though mean hemi-spherical candle-power, or even horizontal candle-power is often used. In the case of gas lamps, however, it is customary to express the light from the lamp in terms of horizontal component in England, though in Germany the use of mean spherical candle-power is somewhat more usual.

These and many such like considerations do, I believe, usually render general comparisons of costs misleading when applied to practical conditions. When the assumptions made are clearly stated they have a certain value for reference, but any lighting engineer must necessarily consider each case on its merits.

Lecture IV.—Delivered March 8, 1909.

GENERAL PROBLEMS IN ILLUMINATION AND ILLUMINATION MEASUREMENTS.

Introduction.

In the previous lectures a very representative collection of different systems of illumination has been described, which may be said to offer almost a bewildering variety of choice to the consumer. I now wish to collect together some of the threads already taken up, and to say a few words upon the actual utilisation of the light available.

I have referred to the alteration in modern industrial conditions, our tendency to use more and more artificial light, and to continue to turn night into day; we now carry out our work in the night time with a facility undreamed of by our forefathers. At the same time we must feel that this very facility carries with it a degree of responsibility with which our forefathers perhaps were not troubled. At one time, before gas and electricity were available, there was no serious attempt to pursue our ordinary vocations by night. A few dim lights served to enable us to see about, but darkness was usually the signal for sleep; now, of course, all this is changed, and the present period, when developments in lighting are proceeding more rapidly than ever, is a fitting time to take stock of the situation.

Let us inquire, in the first instance, whether we are studying sufficiently closely how the light we are at such pains to produce should be actually applied? We may ask how much light is required for different purposes? What quality of light is desirable, what direction the light ought to come from, and how it should be distributed? All these are questions that now demand satisfactory answers.

We may indeed even go so far as to add one question more radical than any, whether, after all, we are doing wisely in proceeding on the course of turning "night into day"? We know how birds, for instance, are affected by climatic conditions. It has been an interesting experience at different zoological gardens in temperate climates to find that tropical birds do not thrive owing to the unequal periods of light and darkness interfering with their sleep. When artificial light was resorted to in order to reproduce the exact conditions of the tropics, the birds recovered their health and slept properly. The depressing effect upon miners of being obliged to work long hours in gloom and darkness is well known, and the melancholy nature of the night watchman's work is proverbial. In addition, it has been found that people who travel from one locality to another where the periods of light and darkness are very different suffer somewhat from this change, but they become acclimatised to the new conditions in time. Is it not, therefore, legitimate to inquire whether we ourselves may not experience certain effects due to physiological actions during the night time, which demand darkness, and whether our attempt to do away with a greater part of darkness might not be injurious to our health and sight?

Daylight Illumination.

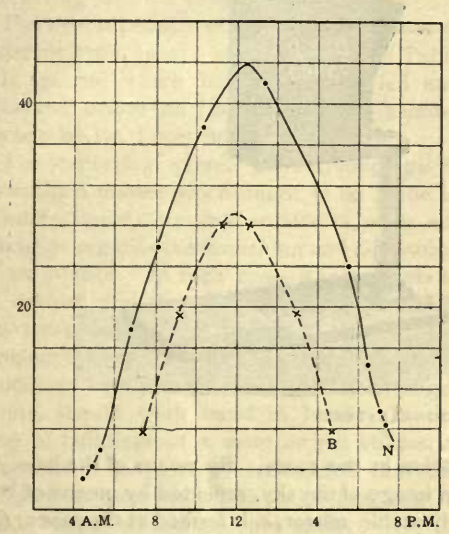
In all these perplexing questions, however, there is perhaps one guide on which we can rely even though we must not follow it too implicitly, namely, the qualities of natural daylight, to the best use of which our eyes have been gradually developed through countless generations. It is, therefore, desirable to say something regarding illumination of this kind, for our acquaintance with daylight conditions naturally modifies our impression of artificial methods of lighting. Yet here again, we must remember that daylight itself must be studied scientifically in order to use it to the best advantage. Both its quality and its intensity differ very greatly at places at different seasons, and at different times of the day. Weber in Germany, and Basquin, Nichols, and others in the United States have studied this question closely.

Some idea of the manner in which the illumination in a room may alter during the day, and at different periods of the year, will be understood from Figs. 65 and 66, which are taken from a paper by Dr. E. L. Nichols before the Illuminating Engineering Society in the United States in 1908. We must not be too ready to assume that because daylight is the natural method of illumination, therefore it can take care of itself and does not need proper attention.

Naturally, provision must be made to secure that such illumination of buildings is sufficient to enable people to carry out their work with comfort. Indeed, it will be found that the actual intensity of illumination at different parts of a room lighted by daylight varies even to a greater extent that when illumi-

nated by artificial light, according to the nature of the windows. In an office in Victoria-street with which I am acquainted, for example, a recent test showed that the intensity of illumination just inside the window at 10.45 a.m. was as much as 50 foot candles, whereas on a desk only 12 feet away from the window it was less than 1 foot candle. The matter of the careful study of daylight illumination in schoolrooms, on which I mean to touch on later, can hardly be over-estimated. When we consider how much work is carried

FIG. 65.



VARIATION IN INTENSITY OF DAYLIGHT DURING THE DAY.
N. Nichols (Tyrol).
B. Basquin (Chicago).

out during the day time, we can see how important the study of the necessary conditions really is.

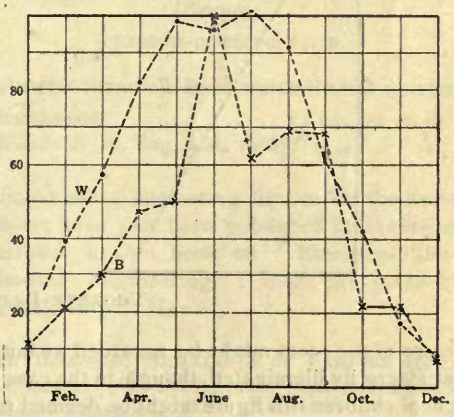
In passing, it might be of interest to mention that Mr. P. J. Waldram has recently been studying the measurement of daylight illumination from the architect's standpoint, and has found actual measurements of very great value in supporting the contentions in connection with cases of ancient lights in court. This is an instance of the unexpected directions in which the value of the measurement of illumination often comes to be felt.

I may also refer to the various efforts that have been made to specify the amount of a window space, &c., in schools and factories, and to pre-determine what the actual illumination is likely to be. For instance, in addition to Mr. Waldram's experiments (*Illuminating Engineer*, Vol. I., pp. 241, 811), Prof. Ruzicka has attempted to prepare a small artificial model of the room under consideration, illuminated by an artificial sky (*Illuminating Engineer*, Vol. I., p. 539).

Naturally such a method of pre-determining the conditions of lighting in a building yet to be erected, might be of considerable value, for it is not always easy for the architect to estimate beforehand whether the access of daylight to long corridors, or even rooms, is adequate.

Since the date of the lectures, Mr. Waldram has published some further results of the application of the above method of testing the day-

FIG. 66.



VARIATION IN INTENSITY OF DAYLIGHT DURING THE YEAR.
B. Basquin (Chicago).
W. Weber (Kiel).

light illumination to interiors. He has explained that under all ordinary conditions, a constant relation can be shown to exist between the intensity of illumination at a certain point in a room, and the unrestricted illumination out of doors. The value of this constant will, of course, depend upon many factors, upon the nature of the window space, the height of the houses opposite, and the reflecting power of the wallpapers used in a room, for example. But for a given room it will have the same value from day to day under widely different climatic conditions, and will, therefore, constitute a rough index as to whether the provision of daylight-access to a room is to be considered satisfactory or no. Of course it may happen that a room for which this constant is regarded as unduly low may nevertheless be sufficiently

illuminated for a part of the day. But as seen above, this is not sufficient; we must prescribe conditions which render it highly improbable for the light ever to fall below the requisite minimum.

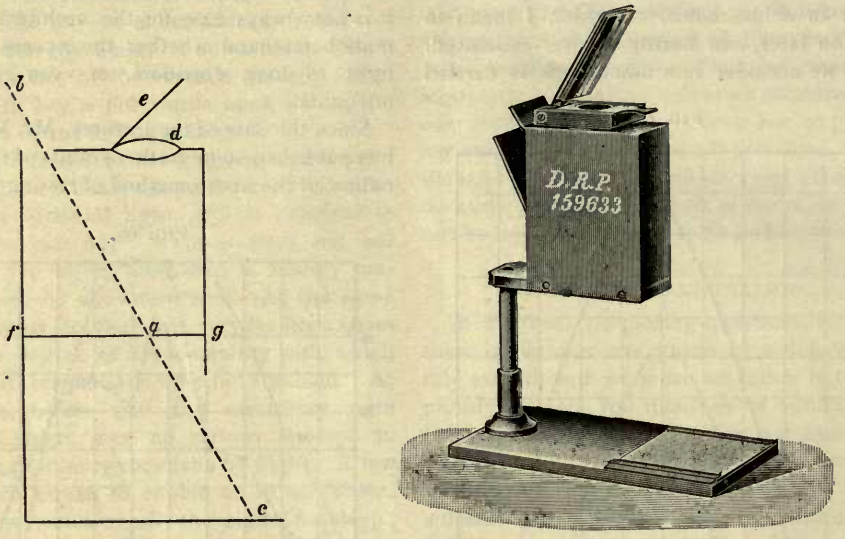
Mr. Waldram considers that an office which enjoys 0·001 of the outside illumination at the centre of the room might be regarded as fairly satisfactorily illuminated, though, in the case of school children this figure might be deemed too low. In the article in question he quotes a series of figures for different buildings in London of which the following are a few examples :—

PROPORTION OF UNRESTRICTED OUTSIDE ILLUMINATION RECEIVED BY INTERIORS OF BUILDINGS.

New suburban elementary schools (children's desks)	0·0025 to 0·008.
New urban technical schools, ground floor average	0·001.
Ordinary offices, average at centre of room	0·001.
British Museum reading-room	0·007.
Royal Courts of Justice, Judges, seats	0·0007 to 0·0022.
House of Commons—	
Clerk's table	0·0008.
Speaker's chair	0·0009.
Members' seats	0·0003 to 0·0007.
House of Lords—	
Woolsack	0·0004.
Members' seats	0·004 to 0·0006.
Charing-cross Station Booking-hall	0·0001 to 0·0003.

Another simple form of apparatus for studying daylight-condition is that due to Thorner which is on exhibition to-night. This arrangement is shown in Fig. 67. The instrument is based on the same principle as that indicated by previous remarks, serving virtually to compare the brightness of the sky at any moment (which is a criterion as to the outside unrestricted illumination), with the actual illumination in the room. By means of the lens, *d*, an image of the sky, reflected by means of the adjustable mirror, *e*, is formed at the paper, *fg*, in which there is a pinhole at *q*. The observer looking along the line, *bqc*, sees the white surface behind this pinhole at *c* and superimposed on this the image of the sky at *q*. Now the surface at *c* is illuminated by the available light in the room just as a book might be. If this illumination is too weak, the spot *q* appears black on a white surface; if, however, the illumination at *c* is to be judged satisfactory the contrary is the case. If the spot seems to be just equal in shade to the image of the sky the conditions are just on the border-line between what is to be considered adequate and what is not. It may be said that in many rooms no sky is visible and therefore the instrument cannot be applied, but it seems to be suggested that this in itself would lead one to consider the daylight conditions unsatisfactory.

FIG. 67.



THORNER ILLUMINATION-TESTER.

THE REFLECTING POWER OF WALLPAPERS, &c.

While mentioning this matter reference may be made to the importance of bearing in mind the reflecting powers of the walls and furniture

in a room and the great influence which such surroundings exert upon the available illumination. In any interior the effective illumination on a book or table consists only partially of the direct rays from the source of light. In addition, valuable assistance is rendered by the light reflected from surroundings. It is also preferable, physiologically, to avoid the extreme contrasts of very dark walls and gloomy surroundings, and the relatively bright surface of the book we are reading, or the paper on which we are writing. With this point we shall deal again in subsequently discussing inverted systems of lighting.

The general nature of the reflecting power of different surfaces will be gathered from Table III. (p. 76) which has been compiled and presented before the Illuminating Engineering Society by Dr. Louis Bell.

The reflecting power of surroundings is naturally a matter which ought to be borne in mind by decorators and architects when advising as regards the furnishing and decoration of an interior. In such cases it is certainly to be desired that the architect, in whose hands the treatment of the æsthetic side of the problem mainly rests, and the engineer, who is concerned with the practical lighting arrangements, should work hand in hand. In the case of buildings of a more or less utilitarian character it may be recommended that the walls of the room should be in general light in shade but tinted and not pure white.

Before leaving this question it may also be pointed out that not only the quantity but the *quality* of light is affected by the surroundings. Thus in a room with red wallpapers the amount of reflected light usually suffices to give the illumination a distinctly reddish tinge, and this, of course, is not without effect on the appearance of coloured objects brought into the room. In the same way the colour of the surroundings must, to some extent, govern the colour of the illuminant which it is preferable to select. For instance, it would clearly lead to a certain loss of light and might be undesirable æsthetically to employ a source which was deficient in red rays and rich in green in a room in which the prevailing tint was red.

Intrinsic Brilliancy.

Turning now to artificial illuminants, I come to speak of one very important respect in which artificial illumination of the present day differs from daylight, namely, in intrinsic brilliancy. We have gradually become accustomed to the use of concentrated sources of light far brighter than the brightness of the normal sky. For instance, Dr. Stockhausen has given the following figures for different illuminants :—

Intrinsic Brilliancy of Various Illuminants (Stockhausen, Zeit f. Beleuchtungswesen, Oct. 10th, 1907).

Source.	Intrinsic brilliancy (c.p. per sq. in. of radiating surface, approx.).
Petroleum lamp	20
Incandescent mantle	35
Carbon filament glow-lamp ..	540
Metallic ,, ,, ..	1,100
Nernst ,, ,, ..	2,250
Arc light (Crater)	17,000

Average Intrinsic Brilliancy of Sky (Basquin).

3·5 candle-power per sq. in.

Minimum Intrinsic Brilliancy Recommended.

Stockhausen	4·2 c.p. per sq. in.
Woodwell (Ill. Eng. Soc., 1908)	0·1 ,, ,, ,,

Some other interesting figures on the same subject have just been published by Professor Barrows in his book on "Electrical Illuminating Engineering": these are given in the following Table :—

The Intrinsic Brilliancy of Various Illuminants. (W. E. Barrows, *Electrical Illuminating Engineering*.)

Nature of Source.	Candle-power per sq. inch.
The Moor Tube	0·6
Frosted incandescent lamp	2-5
Candle flame	3·4
Gas flame	3-8
Oil lamp	3·5
Kerosene lamp	4-8
Cooper Hewitt lamp	16·7
Welsbach gas mantle	20-25
Acetylene flame	75-100
Enclosed a.c. arc depending on globe	75-200
Enclosed d.c. arc depending on globe	100-500
Incandescent lamp 4 watts per candle	300
Incandescent lamp 3·5 watts per candle	275
Incandescent lamp 3·1 watts per candle	480
Gem lamp 2·5 watts per candle	625
Tantalum lamp 2 watts per candle	750
Nernst lamp (bare)	800-1000
Tungsten lamp 1·25 watts per candle	1000
Sun on the horizon	2000
Flaming arc	5000
Open arc lamp	11000-50000
Open arc crater	200000
Sun 30° above the horizon	500000
Sun at zenith	600000

TABLE III.

TABLE OF COEFFICIENTS OF DIFFUSE REFLECTION (Dr. Louis Bell).

Kind.	Colour.	Coefficients for Skylight.	Incandescent Lamps.	Remarks.
Plain ceiling	Faint greenish	·50	·53	—
,, ,,	Light ecru	·27	·26	—
,, ,,	Very faint grey cream	·53	·64	—
,, ,,	Light grey cream	·26	·23	—
,, ,,	Light yellow	·53	·49	—
,, ,,	Faint ecru	·47	·55	—
,, ,,	Faint pinkish	·41	·43	—
,, ,,	Pale bluish-white	·42	·31	—
Crêpe	Medium green	·25	·19	—
,,	Darkish coffee brown	·08	·06	—
,,	Deep green	·05	·06	—
,,	Deep yellow buff	·41	·41	—
,,	Full green	·06	·06	—
,,	Deep red	·05	·05	—
,,	Medium red	·06	·01	—
Cartridge	Medium green	·15	·11	—
,,	Dull green	·11	·07	—
,,	Dull yellowish-green	·09	·07	—
,,	Light pinkish-brown	·21	·26	—
,,	Light green	·23	·18	—
,,	Light blue	·21	·30	—
,,	Pale grey	·35	·27	—
,,	Faint yellowish green grey	·43	·33	—
,,	Salmon buff	·31	·33	—
,,	Medium light buff	·44	·44	—
,,	Medium full green	·11	·07	—
,,	Medium dull red	·06	·07	Grey red
,,	Light red	·10	·10	—
,,	Very deep ecru	·18	·15	—
,,	Pale pink	·25	·19	—
,,	Deep yellow grey	·18	·15	—
Silky finish	Medium crimson	·08	·12	Across grain
,, ,,	Medium grey green	·17	·12	—
Stripes	Deep cream	·56	·60	—
,,	Deep cream silvery	·56	·57	—
,,	Yellow medium	·50	·53	—
,,	Deep buff	·53	·58	—
,,	Medium red	·06	·08	—
,,	Medium red satin	·07	·11	—
,,	Light strawberry pink	·43	·43	—
,,	Light strawberry silvery	·51	·49	—
,,	Light and dark green	·06	·07	Heavily streaked deep green
,,	Silvery light	·13	·14	—
,,	Light green	·36	·26	Plain
,,	Silvery light green	·36	·23	Corded
Miscellaneous	Dark green and gold	·24	·19	Minute figuring with much gold
,,	Light green and gold	·31	·28	—
,,	Deep and light red	·12	·20	—
Piqué	Light bluish	·46	·47	—
,,	Light grey	·38	·38	—

After each fresh departure in our methods of illumination, it invariably takes some time for people to get accustomed to the new conditions. It is interesting to recall the comments of the great chemist, Clement Desormes (see Cantor lecture by Professor W. Grylls Adams, F.R.S., 1881), who in 1819, when the gas light was first introduced, said:—

"The light is of a disagreeable yellow colour, entirely different from that red and warm gleam of oil lamps; it is of a dazzling brightness; its distribution will be impossible and irregular, and it will be much dearer than oil lighting; and, even if it should be improved, it will still remain much dearer than those lights which we already possess."

To-day, when we are accustomed to sources so much brighter than the flat flame gas burner this comment may seem amusing. But let us pause a little. It is in fact now realised by those who have studied illumination that this quality of intense intrinsic brilliancy is one of the seriously inconvenient qualities of modern sources of illumination. Most of you will at once concede how unpleasant is the dazzling effect of looking straight at an arc lamp, high pressure gaslight, or a naked metallic filament glow lamp at close quarters. You will find that after looking steadily at such a source for a few minutes, and then shutting the eyes, a distinct "after-image" is perceptible, which may appear to fade away in a few minutes, or even seconds, but which certainly corresponds to some abnormal, and therefore possibly injurious effect on the state of the eye.

In order to illustrate this point an analogy may be drawn with the action of a photographic plate. When a photographic plate receives a luminous image upon it, it is immediately affected and retains the image owing to a chemical change in its constituents. This only reveals itself when the plate is subsequently developed. But the plate can be kept undeveloped for some time, and though apparently unaffected as far as appearance goes the image is still there. Yet some observers have stated that, provided the plate is kept long enough, the image weakens with time, and has been known to fade away at last; the plate therefore seems to resemble the eye in recovering from severe exposure very gradually. This interesting analogy might well be made the subject of further study.

But on the other hand we know that an underexposed plate reveals but a faint image, and if the stimulus be sufficiently weak no perceptible image is retained at all. In the same way the eye, when exposed to a severe luminous impression, tends to retain the image afterwards and fails to recover immediately its normal condition; but an image which is not unduly bright passes away and leaves no apparent traces.

It might be mentioned that a very severe exposure indeed may produce local disturbances in vision which persist for a very long time; for instance, Prof. G. J. Burch has recorded inconveniences of this kind in his own case as the result of incautiously experimenting in connection with this very subject. In addition he has found that when we are removed into a completely dark room, these "after-images" on the eye sometimes seem to be still traceable after a couple of hours of complete rest.

We may also compare what happens when a photographic plate is exposed to a very bright object such as, for example, the windows in a somewhat subdued interior. Under these conditions we know that the image of the bright object is not sharply defined. There is "halation," and the outlines of the bright surface are surrounded by a misty halo owing to the spreading of the chemical effect beyond the proper limits. Even so our vision seems to be impaired when gazing at bright objects. The filament of an incandescent electric lamp, for example, appears much thicker to the eye when incandescent than when in the unheated state.

Bearing in mind the order of brightness of the sky, which Prof. Basquin, as the results of experiments in the United States, extended over a long period, has estimated to be on the average in the neighbourhood of 3·5 candle-power per square inch, some authorities have recommended that the intrinsic brilliancy of sources of light liable to fall in the direct field of vision, should not exceed 5 candle-power per square inch. More recently, however, it has been felt that even this value was excessive in the cases of sources comparatively near to the eye, and Drs. Schanz and Stockhausen and also Mr. J. E. Woodwell (Paper read at the Annual Convention of the Illuminating Engineering Society, United States, 1908; *Illuminating Engineer*, Vol. I., p. 80) have recommended a value of not more than about 4·2 and 0·1 candle-power per square inch, respectively.

Before leaving this subject I should like to refer to the manner in which my previous comments on the subject of intrinsic brilliancy have been misconstrued, and in some cases, I fear, deliberately distorted. I urged, and with justice, when reading a paper be-

fore the meeting of the British Association at Leicester in 1907, that the new electric metallic filament lamps would undoubtedly have an injurious effect on the eyes if placed in the direct line of sight. In other words, this new source must be properly used and not abused. Unfortunately the gas interest in one of their publications utilised my warning without also mentioning in detail the circumstances under which it applied, thus giving the impression that I was responsible for the statement that the electric light was injurious to eyesight. I take this opportunity of pointing out that modern incandescent gas-lights used under the same faulty conditions, in the same careless manner, would also be objectionable.

I do not, however, wish to dwell on this aspect in any alarmist manner, but only to point out that this defect must be faced, and probably can be met by comparatively simple precautions. The obvious moral is that such bright sources ought to be kept out of the field of view of the observer, or if visible, their brilliancy ought to be suitably reduced by the effective use of shades. Apart from the possibility of physiological injury, common sense tells us how absurd it is to try to see any object with a bright source in between this object and the eye. If we are in a brightly lighted room our eyes adjust themselves to the brightness within but are incapable of seeing anything outside in the darkness; on the other hand, a person out in the dark can see into a lighted room without being seen himself. This fact ought to be borne in mind by the shopkeeper who deliberately places bright sources of light in front of his goods in his window; as a natural result the pupil orifice of the eye and the retina adjust themselves to this bright object and those objects which are only illuminated by a moderate intensity cannot be seen. In this connection I should like to speak with approval of the recent action of the City authorities in specifying that such bright sources should be screened in the direction facing the street, so as to avoid their tendency to dazzle the drivers and pedestrians. I may quote an effective motto recently put forward in one of the Holophane Illumination publications, "*Light on the object, not in the eye.*"

We may, in fact, regard it as an axiom that any source of light itself must be regarded as the crude product until it is effectively screened with a suitable diffusing shade; in America it has now become customary to supply "units" which consist of a source, perhaps an incandescent glow lamp equipped with a suitable reflector or globe, and seldom used without this combination. Indeed, so serious is the effect on the eyes of brilliant unscreened sources in the direct range of vision now felt to be, that I would almost consider the time ripe for definite governmental recommendations that such sources must invariably be provided with a suitable diffusing screen or shade, which will adequately protect the eyes.

There is really nothing very revolutionary in proposing recommendations of this description on such a vital point. But a few years ago, the importance of such questions as ventilation and purity of air was hardly generally realised, and those who insisted upon the need for supervision of these conditions in factories, were looked upon as extremists. At the present time, the importance of pure air, through gradual and persistent effort, has come to be so generally appreciated that factory inspectors are in a position to make strong recommendations on the subject, and even to prosecute when the conditions are clearly unjustifiable. And as interest in the subject has increased, so have methods of testing become more precise. At the present day, valuable evidence can be obtained from the chemical analysis of samples of air in buildings, which are enclosed in small bottles, taken away by the inspector, and forwarded for examination to a central laboratory. Similar progress may be looked for in connection with illumination.

Another illustration of the result of convictions on hygienic matters gradually born home is the recent determined attempt to eradicate the objectionable habit of spitting. Once it came to be generally appreciated how vital was the importance of restricting this source of propagation of tuberculous disease the restriction met with little opposition. But what an outcry such a suggestion, interfering with the license previously enjoyed, would have raised a few years ago!

In the same way it may be suggested that a few wholesome regulations regarding obviously desirable improvements in existing methods of using light will soon be regarded as perfectly natural. It is quite as important to eradicate a foolish and unreasonable practice which is bad for the eyes, as it is to take due measures for the preservation of public health in other respects.

It may, therefore, next be of interest to discuss briefly a few of the methods of reducing the intrinsic brilliancy of illuminants by suitable shading.

Most of you are familiar with the use of the opalescent and opal glass for this purpose, and may know too that frosted glass has been very frequently utilised, especially in connection with electric lamp bulbs. In addition, in our drawing-rooms we frequently have recourse to silk shades in order to tone down the brightness of portable lamps distributed about the room.

Such methods may, of course, serve the purpose of producing a suitable diffusing surface; unfortunately, in so doing it is difficult to secure really adequate diffusion without at the same time losing an enormous amount of light.

I may mention, for instance, some data relating to the absorption of different types, which have been published by Professor J. T. Morris, Dr. B. Monasch, and Professor Barrows.

THE ABSORPTION OF VARIOUS GLOBES (W. E. Barrows, *Electrical Illuminating Engineering*).

		per cent.
Clear glass	globes absorb from	5-12
Light sand blast	,, ,,	10-20
Alabaster	,, ,,	10-20
Canary coloured	,, ,,	15-20
Light blue alabaster	globes absorb from	15-25
Heavy blue alabaster	,, ,,	15-30
Ribbed glass	,, ,,	15-30
Opaline glass	,, ,,	15-40
Ground glass	,, ,,	20-30
Medium opalescent	,, ,,	25-40
Heavy	,, ,,	30-60
Flame glass	,, ,,	30-60
Signal green	,, ,,	80-90
Ruby glass	,, ,,	85-90
Cobalt blue	,, ,,	90-95

(*Professor J. T. Morris*).

		per cent.
Clear glass	globes absorb from	14·8
Slightly opalescent	,, ,,	23·8
Small opal	,, ,,	17·2
Large opal	,, ,,	21·7

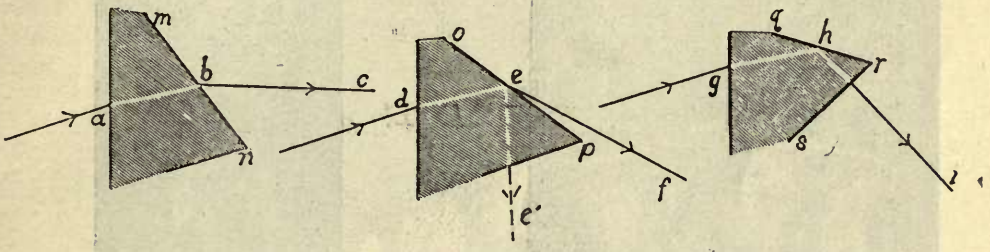
(*Dr. B. Monasch, Elektrische Beleuchtung*).

		per cent.
Clear glass	globes absorb from	9·2
Opal	,, ,,	17·1
Alabaster	,, ,,	33·8

In addition, such methods only serve the purpose of reducing brightness; they are not effective in directing the light where required, or concentrating it on any particular spot.

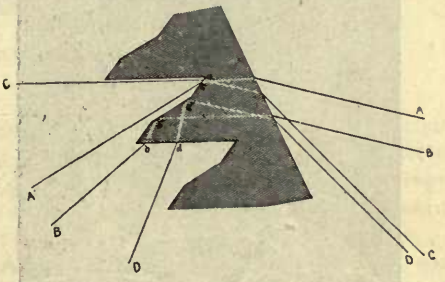
These considerations have led to the introduction of a type of scientific glassware, of which we have some notable examples on exhibition. Cut glass has for a long time been utilised for the purpose of diffusing light sources. In the cut glass globes used until recently, however, such grooves as were made in the glass were only made quite haphazard, with the result that although a certain amount of diffusion was obtained, there was no attempt at direction, and the amount of light through any such globe having no appreciable diffusing power was very small indeed.

FIG. 68*a*.



Refraction. Refraction and Reflection. Total Reflection.

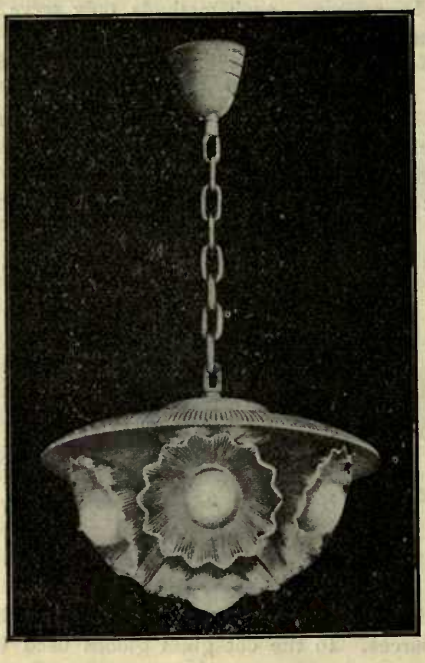
FIG. 68*b*.



About 25 years ago, however, some experiments were carried out by Mr. A. P. Trotter in this country, and M. Blondel and subsequently by M. Psaroudaki in Paris, with the object of making scientific prismatic glassware which should not only absorb a minimum amount of light, but should diffuse it and also distribute it in any desired

direction in a scientific manner. At that time the inventors may be said to have been far ahead of their age, and, therefore, we once

FIG. 69.



HOLOPHANE CLUSTER.

FIG. 70.

HOLOPHANE REFLECTORS ENCIRCLING LAMPS WITH FROSTED TIPS.

more meet with an instance of early pioneering work in this country which has subsequently led to successful developments in illumination. For some years past the Holophane Company in the United States have taken up the question with great energy, and are manufacturing many models of fixtures of this kind for use with gas, electricity, or any other illuminant that may be desired, and designed specially with the object of utilising the light scientifically.

In this connection I might quote the action of the Franklin Institute in Pennsylvania, who in 1897 awarded the John Scott Legacy medal and premium to Messrs. Blondel and Psaroudaki, for their invention of a globe which secured much better diffusion and more

FIG. 71.

HOLOPHANE DIFFUSING GLOBE.

satisfactory distribution than any other globe known to its members.

The general nature of the prisms of which this scientific glassware is composed will be understood from Figs. 68*a* and 68*b*.

Fig. 68*a* shows the course of the rays through the simpler form of prism employed by the older inventors. It will be observed how the rays are bent out in different directions according to the inclination, and it will also be readily understood how, in utilising Holophane glass, it is essential to employ only a globe or reflector intended for use with the lamp for which it is specially designed. In Fig. 68*b* will be seen the more complete

prismatic arrangement adapted by M. Blondel and M. Psaroudaki, which enabled the light to be spread over a wider angle and distributed more perfectly in the desired directions than was permitted by the simple prism arrangement.

When it is desired to distribute the light in a room, the individual rays from the source pass through the prismatic ribs and are reflected and refracted in a scientific and uniform manner so that each spot on the surface of the enclosing globe virtually becomes a new distributing centre; thus the light coming from the source is spread over an extensive surface, and the glare of the concentrated source is replaced by an apparently uniformly illuminated globe.

In addition, this naturally serves to distribute the light effectually in all directions and to remove that "streaky" appearance, which is the result of the lack of uniformity in the distribution of light from most naked sources. The use of a shade of this kind also gives rise to a "soft" light; that is to say, there are no unduly sharp shadows. For instance, if the Holophane globe is removed and the lamp hangs naked below the metal holder the result is a dark shadow on the ceiling which appears irregularly illuminated; this, however, gives way to apparent uniformity and absence of shadow when the Holophane globe is replaced.

In many cases, what we chiefly desire is to distribute the light evenly in all directions, and Holophane globes may be designed with this object. In other cases, however, we desire the greater portion of the light to be reflected at a certain angle, in a downward or upward direction, and this, by a slight modification in the shape of the crystals, can also be done.

A number of examples of diffusing and concentrating Holophane globes and reflectors are on exhibition to-night. (Figs. 69, 70, 71, 72.) The glass reflectors are perhaps of special interest, because they are so designed that while concentrating the great bulk of the light in a downward direction where it is wanted, they also allow a small amount to pass in an upward direction; therefore we may mount a a suitable silk shade over such a reflector and we shall have the advantages of efficient reflection, and yet enough light coming upwards to

Fig. 72.

Holophane Globes in Position Illuminating a Verandah.

make the shade appear ornamental. Metal reflectors do serve the purpose of concentrating the light, but, of course, have not the above-mentioned property.

Glassware of the Holophane type can be applied with success to all the various methods of illumination, gas, oil, electric light, &c., and new designs are constantly brought out to suit the different types of lamps as they come upon the market. One feature of special importance, as mentioned previously, is the supply of a given lamp, with its appropriate shade, as a single unit. In this way the most efficient results are secured to the consumer who is taught to consider any lamp incomplete unless it is properly shaded. I have dwelt on this matter in some detail because during my recent visit to the United States, where scientific illuminating engineering has received so much attention, I found that this scientific glass was very widely used.

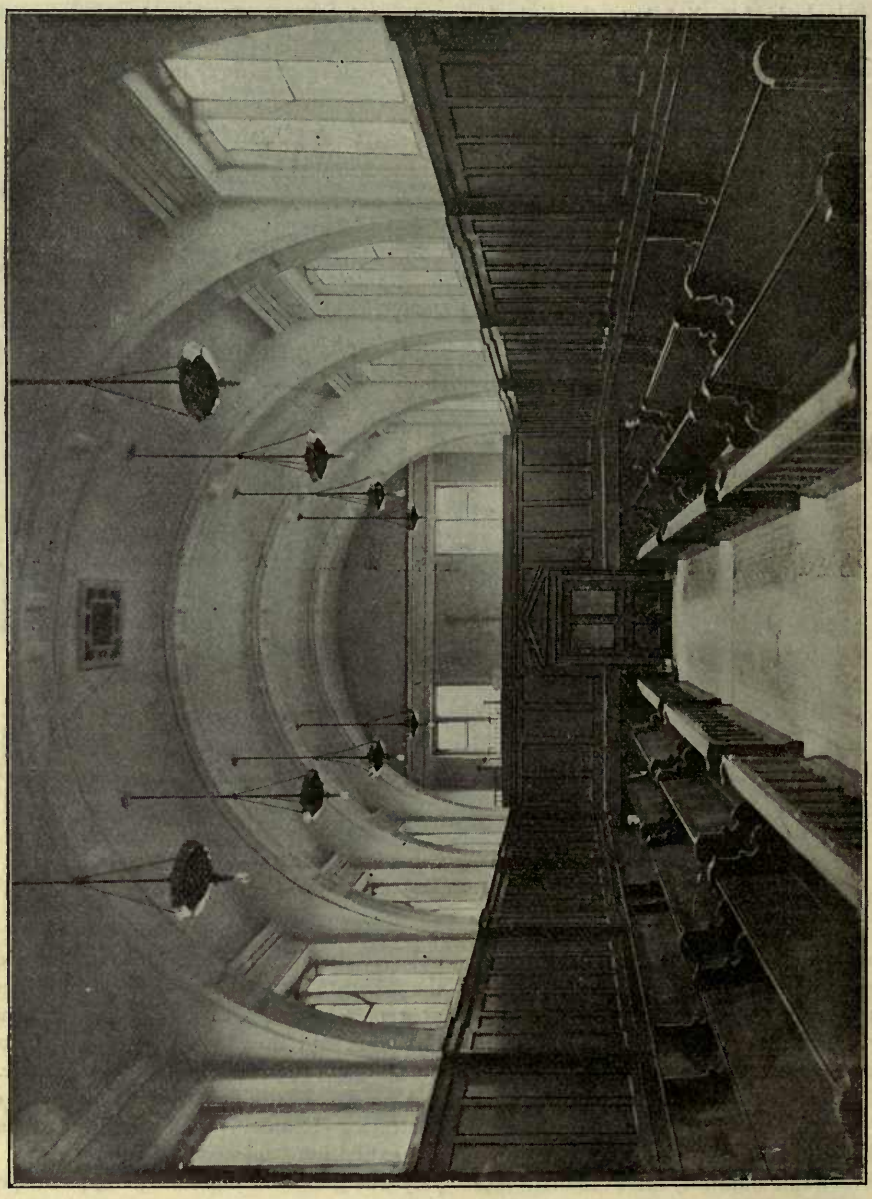


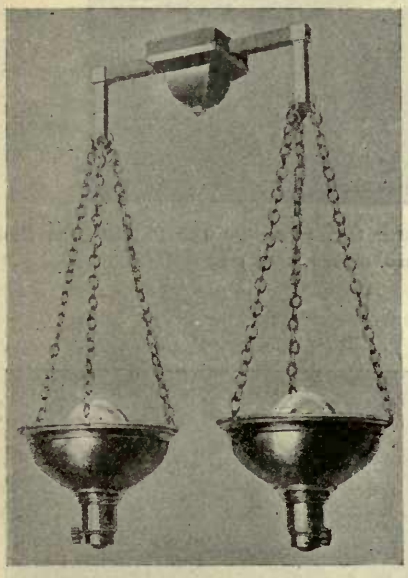
FIG. 73.

ILLUMINATION OF MANCHESTER INFIRMARY CHAPEL BY INVERTED TUNGSTEN LAMP-FIXTURES.
(By the courtesy of the *Electrical Field*.)

Indirect Lighting.

While speaking of methods of diffusing light mention may be made of the inverted system of lighting by means of which all the direct rays of a source are thrown on the ceiling, and the eye therefore receives no direct rays and an approximately shadowless illumination can be obtained. Formerly this method was used in connection with arc lights and high-pressure incandescent gas lights, but the coming of the high candle-power efficient metallic filament glow lamp may lead to its more general adoption than hitherto. Figs. 74 and 75 show some examples of this

Fig. 74.



Twin Inverted Electric Fixture.

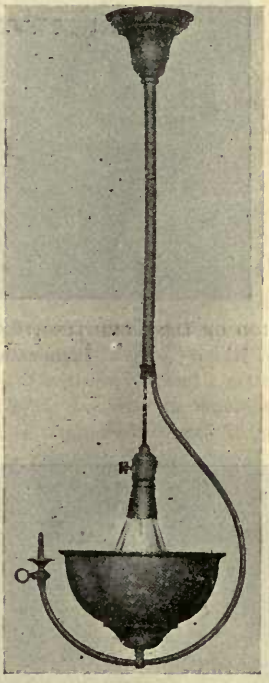
(A. D. Curtis and A. J. Morgan, "Trans. Illum. Eng. Soc." 1908).

method, recently described in a paper before the Illuminating Engineering Society of New York.

At one time the production of an entirely shadowless illumination was held to be very desirable, as it corresponded with a close resemblance to daylight conditions. More recently, however, illuminating engineers have come to feel that an intermediate condition of things is desirable. We do not want very sharp contrasts of light and shade, which are admittedly trying to the eye, but, on the other hand, artistic and even utilitarian requirements rarely favour entire lack of shadow.

It has been suggested, for instance, that, when reading a book, we do not desire the surroundings to be too bright in comparison, for this tends to distract attention. It has recently been found in New York that indirect systems were sometimes inconvenient in this respect when the walls of the rooms were very light in texture. If the book we are reading is somewhat brighter than the surroundings, however, our attention is involuntarily rivetted on the page, and when our eye does stray

Fig. 75.



Combined Gas and Inverted Electric Fixture.

(A. D. Curtis and A. J. Morgan, "Trans. Illum. Eng. Soc." 1908).

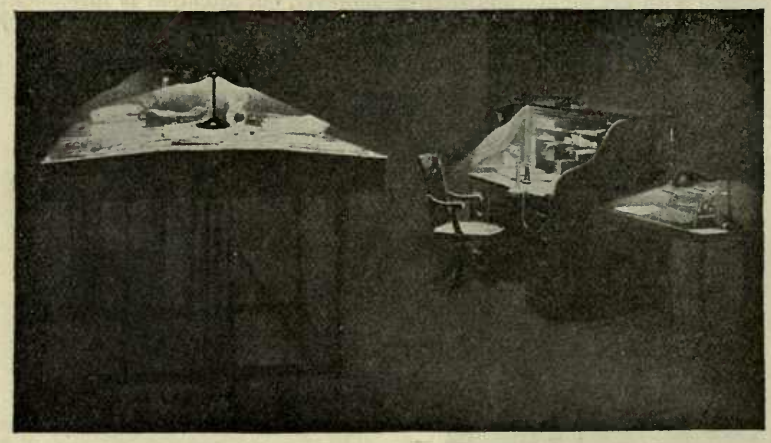
away it is rested by the more subdued tone of the surfaces on which it plays. On the other hand, it is pointed out, when there is light everywhere the eye gets no such rest.

But we must certainly avoid going to the other extreme. Dr. Louis Bell, for instance ("The Physiological Basis of Illumination," Proc. Am. Academy of Arts, 1907) has pointed out that it is very undesirable for a desk to be brilliantly illuminated while the surroundings are in complete obscurity. Under these conditions the eye is not rested when it strays from the book, but receives a positive

shock owing to the change in the conditions. Each time it turns away, the pupil-aperture and the retina attempt to accommodate themselves to the darkness, and, having done so, are called upon to reverse the process once more, when attention is again bestowed on the brightly-illuminated book on the desk.

Fig. 76, which is taken from the communication of Dr. Bell to which reference has just

FIG. 76.



BAD METHOD OF DESK-LIGHTING, EXCESSIVE CONTRAST. (Dr. L. Bell, "The Physiological Basis of Illumination," Proc. Am. Akad. of Arts, 1907.)

FIG. 77.

DESK LIGHTED BY REGINA ARC LAMP, HUNG HIGH AND GIVING RISE TO A GENERAL MODERATE ILLUMINATION.

been made, is presented as a bad example of extreme contrast in this respect.

As an illustration of an attempt to secure more uniform conditions for desk lighting, we may take Fig. 77, which shows a desk illuminated by the diffused illumination from a Regina arc lamp hung high up. Probably it will eventually be recognised that the wisest course in this matter is an intermediate one. Thus we shall feel it advisable to secure a fairly low, subdued general illumination—such as may conveniently be produced by an indirect method of lighting—and to superimpose a stronger local illumination at the desk or table where we wish to work, and on which we wish to concentrate our attention. It will be seen, therefore, that it must not be too readily assumed that inverted lighting pure and simple, which some people have supposed to be the closest equivalent to daylight conditions, is necessarily invariably the ideal method of lighting.

Photometry.

Let me now turn to one branch of the subject of illumination, as it is considered at present, in which very great developments have been made in recent years, namely, the science of *photometry* and the *measurement of light and illumination*. Now, this is a very vast subject, which has been very fully treated by Sir William Abney, Mr. Dibdin, and by the authorities who have lectured before this Society in the past. I cannot hope, therefore, to go into details, but only to refer to one or two respects in which there have been such striking modifications from the point of view from which these matters are regarded.

At one time photometry was regarded merely as an interesting and perplexing scientific playground. Its vital application to practical problems was hardly realised. To-day matters are very different. We have at our disposal a bewildering choice of illuminants, many of them competing very closely in certain fields, and we need every method available of discriminating between their respective values. People now realise that the fundamental use of a source of light is to *illuminate*, and, therefore, it is obviously essential to systematise our methods of comparing their illuminating powers; photometry, therefore, has become an art of industrial importance.

There have of late been a large number of ingenious types of photometers brought forward, so that to-day we have a choice of a number of excellent instruments, where a few years ago there were, perhaps, only two or three that were generally known. We have seen, for instance, the development of the "Flicker" photometer as a means of comparing the brightness of sources which differ in colour.

Illumination-Photometers.—But perhaps the most striking in principle has been the introduction of instruments intended to measure, not the illuminating power of sources, but the actual illumination available in the street, or at the table at which we sit.

Naturally, it is essential to have a method of comparing the illuminating power of sources, but this after all, though of technical importance, is only a step towards the attainment of our ultimate desires. What we really desire to know is the actual working illumination available.

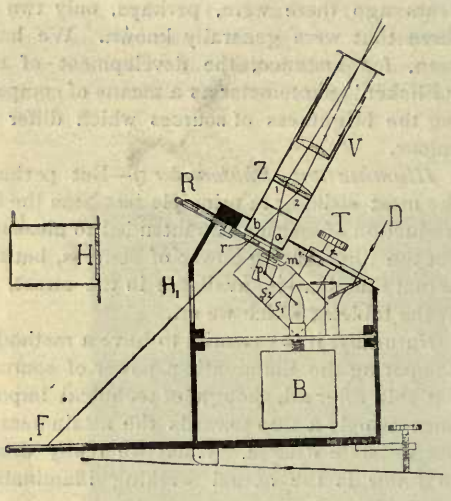
In this connection, it is very interesting to recall some words of Sir William Preece, in a paper before the Royal Society, in 1883:—

> "I have long felt," he said, "that to meet the case of electric lighting illumination, we must not depend upon any direct comparison between the light emitted by the source to be measured, and a given recognised standard of light; but that we should rather make our standard of comparison an area illuminated to a given intensity whatever be the source of light. We do not want to know so much the intensity of the light emitted by a lamp as the intensity of the illumination of the surface of the book we are reading, or of the paper on which we are writing, or of the walls on which we hang our pictures."

Moved by these considerations, Sir William Preece and Mr. A. P. Trotter were among the very earliest in this country to devise the "Illumination-Photometer," or, as they are now sometimes called, "Illuminometers."

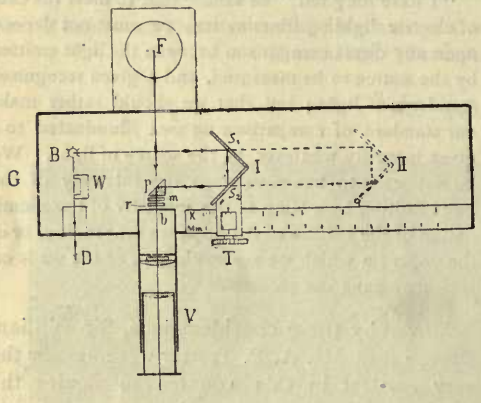
Quite recently the development of an interest in illumination has led many to realise the practical importance of such instruments, and types have been designed in England by Mr. H. T. Harrison, Messrs. Everett Edgcumbe and Co., Messrs. Alexander Wright and Co., and others. For a description of these and other instruments I should like to refer you to a lecture delivered by Mr. J. S. Dow at the Municipal Building and Public Health Exhibition in 1908 (see *Illuminating Engineer*, Vol. I, 1908, pp. 493-506). In addition a very large number of these instruments have been brought forward in Germany and the United States, and some of them formed the subject of an interesting paper by Mr. Preston Millar at the First Annual Convention of the Illumin-

FIG. 78*a*



Elevation (Side).

FIG. 78*b*.



Plan.

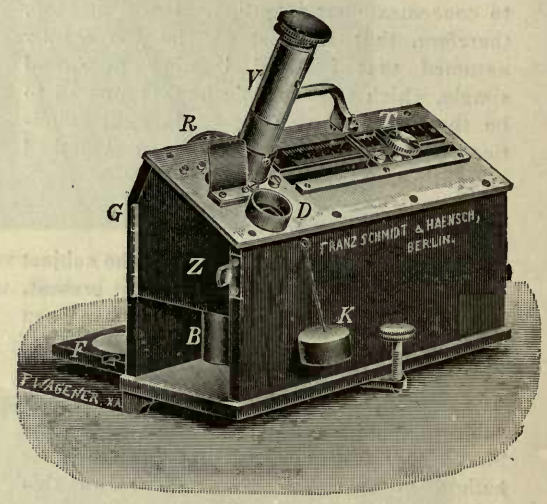
The plaster of paris surface, F, receives the general illumination, the intensity of which it is desired to measure. The rays from this surface pass into the telescope of the instrument at *b*; its brightness is compared with that of the frosted glass, *m*, illuminated by the small benzine lamp, B, the rays from which enter at *a*. The flame-height of this lamp is regulated to exactly 20 mm., this height being controlled by observations through the window at D. The rays from the benzine lamp, before proceeding to illuminate the plate, *m*, must suffer reflection from the pair of mirrors, S_1, S_2, as shown. By moving these mirrors to and fro by means of a rack and pinion arrangement, we can weaken or strengthen the brightness of the illuminated plate, *m*, and can determine the relative values of the intensity of illumination, corresponding to equality of brightness in the field of view, by means of a scale calibrated direct in lux.

This alone would enable a range of illumination of 15 to 1 to be measured; in addition, a disc, *r*, is inserted in front of the plate *m*, which contains a series of graduated smoked glasses, the densities of which are such that the illumination read upon the scale must be multiplied by 0·01, 0·1, 1, 10, and 100 respectively.

ating Engineering Society in 1907. What I wish to impress upon you is, however, that we have now available actual instruments for the measurement of illumination as opposed to light, and that, therefore, we may hope in the future to be able to specify the amount of illumination to be required to read by or for any other purpose, just as a grocer supplies one pound of tea neither more nor less—that is, if he is an honest grocer.

The Globe Photometer.—In passing, I may also mention one important development in light measurement, namely, the introduction of so-

FIG. 78*c*.



General View.

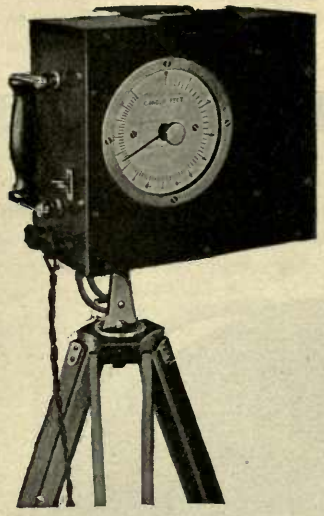
THE MARTENS ILLUMINATION-PHOTOMETER.

called integrating and globe-photometers, which are instruments devised to enable the total amount of light in all directions from a source to be obtained by a single measurement.

Fig. 81 and 82 display typical Ulbricht Globe Photometers; this instrument was discussed very fully by Dr. L. Bloch, Dr. Corsepius, and others in recent articles contributed to the *Illuminating Engineer* (Vol. I., 1908, pp. 274, 553, 801, &c). For detailed information readers are referred to these articles.

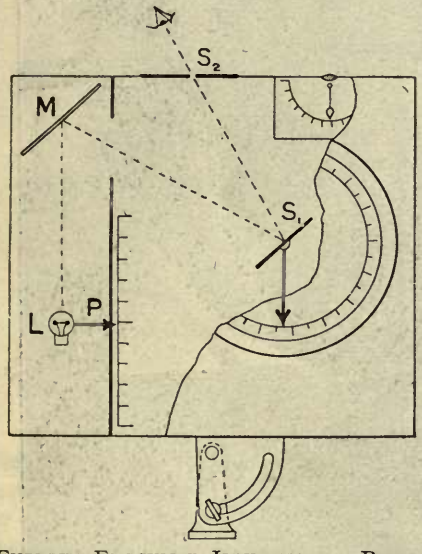
Briefly, however, the principle of the instrument is as follows:—The source, the light from which we desire to measure, is inserted within a hollow sphere, the interior surface of which is coated with some white diffusely-reflecting material. All the rays from the source in all directions are then reflected to and fro within the globe so that the intensity of illumination of the inner surface ultimately comes to be a

FIG. 79*a*.



EVERETT EDGCUMBE ILLUMINATION-PHOTOMETER. (General View.)

FIG. 79*b*.



EVERETT EDGCUMBE ILLUMINATION-PHOTOMETER. (Sectional View.)

The comparison source of light is in this case a small glow-lamp, L, the rays of light emitted by which strike the mirror, M, and are thus reflected on to the white diffusing screen, S_1, receiving the illumination it is desired to measure. The observer looks at the white diffusing screen, S_2; in this is cut a small aperture with very sharp edges. The observer is thus able to compare the brightness of the actual illumination of the surface, S_2, with that of the screen, S_1. The latter can be rotated so that the light strikes it at various inclinations, and the illumination is thus altered through a definite and convenient range from zero to two candle-feet. The actual value in candle-feet is obtained by observation of a pointer attached to the screen, S_1, moving on a scale on the outside of the box containing the photometer as shown in the diagram.

FIG. 80*a*.

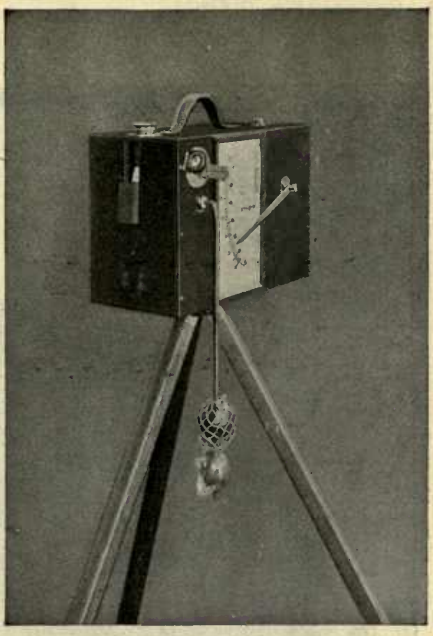
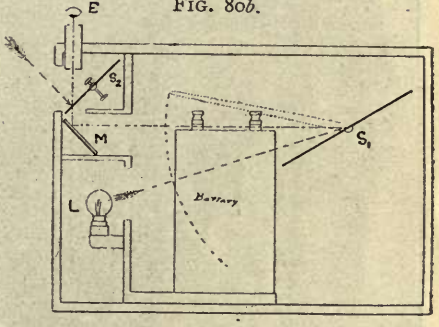


FIG. 80*b*.



HARRISON UNIVERSAL PHOTOMETER
(Messrs. Elliott Bros.).

The standard of light consists of a small glow-lamp at L, which receives current from a small accumulator within the instrument, and which illuminates the moveable screen S_1. S_2 represents a white sector-disc (*i.e.*, a disc from which two symmetrical sectors are cut out) which is driven by means of a small air-blast at any desired speed; on this screen is received the illumination which it is desired to measure.

The eye of the observer at E sees, in rapid succession, first the illuminated white surface of the sector S_2, and then, in the mirror M, the illuminated surface of the screen S_1. All that is necessary, therefore, is to alter the inclination of the screen S_1 until no flicker can be perceived by the eye. The surfaces S_1 and S_2 then appear equally bright. The actual illumination at the screen S_2 can be read off by the reading of a pointer attached to S_1, and moving on a scale graduated in candle-feet. In the position shown in the diagram the photometer is arranged to measure the intensity at an angle of 45 degrees to the vertical, but, by tilting the photometer, the intensity at any measured angle may also be obtained.

In a recent modification of the instrument provision is made for the observer to use the instrument *either* on the flicker or equality of brightness plan, and also for the measurement of illumination in a horizontal plane to be accomplished.

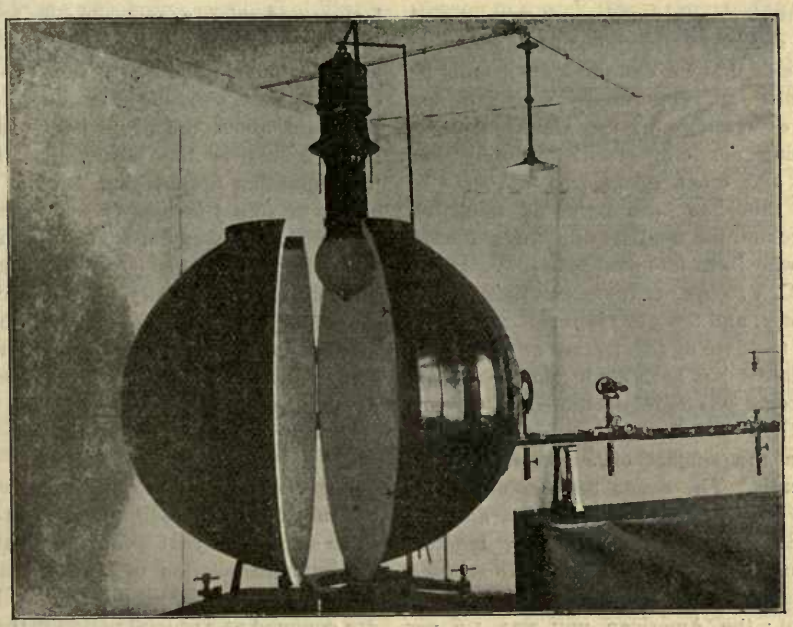
FIG. 81.

GENERAL VIEW OF THE GLOBE-PHOTOMETER.

(*See* Bloch, *Illuminating Engineer*, Vol. I., 1908, p. 280.)

measure of the total amount of light given out by the source. If need be the two hemispheres may be first separated as in Fig. 82 and the lamp placed inside. The two halves can then be closed again and the illumination of the inner surface studied through a little observation window. As a rule, it is unnecessary to open the globe, the lamp to be tested being merely lowered through a suitable hole at the top. As will be seen from these illustrations such globes are frequently of considerable size.

FIG. 82.



VIEW OF ULBRICHT GLOBE PHOTOMETER: THE GLOBE IS DIVIDED IN ORDER TO RENDER ITS INTERIOR ACCESSIBLE.

This is necessary because the theory of the instrument demands that its dimensions should be as large as possible in comparison with the lamp studied, and the instrument is frequently used for the testing of large arclamps, &c.

I wish to repeat, therefore, that the subject of the measurement of light is now being lifted out of the state of uncertainty in which it so long existed, and is now coming to be looked upon as a feasible and recognised process.

The International Unit of Light.—And lastly, let me dwell upon one aspect of this subject which is particularly satisfactory. I allude to the efforts that are now being made to establish measurements of light on a definite international basis. At one time the units of light in different countries were very different, and, as the general public and even the great majority of engineers did not realise this, much confusion naturally arose in expressing the intensity of different lamps. In addition, the actual methods of carrying out photometrical tests differed very much in different countries, and also (as they do even to-day) between representatives of different systems of lighting even in the same country. Within the last few years, however, Government laboratories have been established in the chief countries of Europe and in the United States, and a determined effort has been made to bring matters to a common basis, and to decide accurately the relations between the standards used in different countries. For this purpose carefully standardised glow lamps are now regularly exchanged and compared between the chief laboratories in England, France, Germany, and the United States. There is now, therefore, no fear that these standards may not be maintained constant, and their relation is accurately known.

The next step will be for all the nations to agree upon a common unit of light, and I am glad to say that considerable progress has been made in this direction; a fair share,

of the credit attaching to these efforts is due to the Illuminating Engineering Society in the United States, who have been working in harmony with the American Institution of Electrical Engineers, and the American Gas Institute, for the furtherance of this end. It cannot, however, be too strongly emphasised that no such agreement could be of permanent value unless it satisfies not only representatives of different countries, but also different representatives of the different systems of lighting in use in those countries. It was with the object of urging this view that I was present at the meeting of the International Electrotechnical Commission in this country last year, and strongly supported the recommendation on that occasion that no definite steps should be taken until an opportunity was provided for the expression of the views of those representing not only electric lighting but also gas and other systems. I am glad to say that this has been borne in mind by the sub-committee dealing with the standard of light, who have co-opted Mr. J. W. Helps and Dr. C. V. Boys, as representatives of the gas industry, and the gas referees.

[Since the date of this lecture an important announcement has been made simultaneously by the recognised official photometrical laboratories in Great Britain, France, and the United States on the subject of a proposed international unit. The ratios between units employed in the chief European nations and the United States have recently been redetermined, and it has been found that those used in France and this country are in practical agreement; the American unit was 1·6 per cent. higher than both, and the German unit 0·9 times this value. The United States have now agreed to lower their unit by 1·6 per cent. so that in future one and the same unit will be employed in Great Britain, France, and the United States, while the value employed in Germany is related to the international unit by the convenient fraction 0·9. Some objection to the term "international unit" has been raised in Germany on the ground that the existence of such a unit strictly demands an adequate international standard (which we have not as yet succeeded in obtaining). But whatever view may be taken in this matter, the practical agreement attained between the units in these three countries is a very satisfactory simplification, and the United States deserve our gratitude not only for having taken up the matter so sympathetically, but also for making a certain concession in lowering their unit as explained above. It may be mentioned that M. Blondel has recently pointed out that a proper name for the international unit is needed and propose the Greek terms "Phos" or "Pyr," or the contraction of a scientist's "Vi" for "Violle" (*Illuminating Engineering*, London, Aug., 1909.)]

One by one, therefore, the various misunderstandings characteristic of photometry are being removed, and we may hope to see in the future this method of measuring recognised to be as definite a process as the measurement of gas, or electricity, or even weight.

We may now turn to another section of my lecture and refer, necessarily very briefly, to a few of the most obvious cases of lighting which deserve particularly careful study. In doing so I ask you to bear in mind what I have just said about the necessity for measuring light. This is the keynote of successful "Illuminating Engineering," for it is only by means of actual measurement, however faulty our apparatus may be, that we can preserve a permanent record of prevailing conditions of illumination. Naturally, our methods are still crude, but immense advances have been made since their practical value has been realised, and I confidently expect yet more remarkable developments in the future.

School-lighting.

I should like first to say a few words upon the subject of school-lighting. It would seem to be so obvious that good illumination bears an intimate relation to health, that the importance of lighting schools, in which children are confined at a crucial period in their physiological development, in a thoroughly satisfactory manner would be admitted at once. I am glad to say that here again the Royal Society of Arts has not been found wanting, for recommendations on this point were made by Mr. Brudenell Carter as far back as 1885 in a paper on the "Influence of Civilization on Eyesight," and again in 1898 on "The Eyesight of Children."

I have no time to quote the exhaustive data that have been accumulated to prove that the eyesight of children steadily deteriorates during school life, but I may say that they are very convincing, not only in England but possibly even to a greater extent in Germany and the United States. I may, however, refer you to an article by myself in the *Journal of the Royal Society of Arts*, of August 21st, 1908, and to a special section in the first number of the *Illuminating Engineer*, Jan-

uary, 1908, in which this matter is exhaustively treated.

Dr. H. Wright Thompson, oculist to the School Board of Glasgow, has found that 35 per cent. of the children in the 67 schools visited by him had more or less defective sight.

Professor Scott in the United States has quoted even higher figures, and summed up his remarks in the mournful words :—

"Because of the lack of attention that is paid to the light actually present in the schoolroom, and because of the great difficulty in adjusting our windows and shades to the varying intensities of the external sources of light, it is not surprising that we should find in our schoolrooms conditions of light so bad during many hours of the day that the reading of ordinary printed matter without undue strain on the eyes is impossible."

We find, indeed, that it is generally admitted, as, of course, it stands to reason it would be, that defective eyesight is, at least, partially due to bad lighting in the schoolroom. The light may be insufficient in quantity and so strain the eyes of the child attempting to read. It may also come from the wrong direction, and Mr. Brudenell Carter has shown how this may affect the attitude of a child seated at his desk, and indirectly affect his growth.

In addition, it must be recognised that each portion of the schoolroom requires separate attention, and presents a separate problem. Thus the children's desks must be adequately illuminated, but special provision is necessary for the illumination of the blackboard and for the table at which the teacher is standing.

Another cause to which short sight has been attributed is the use of type that is too small for the growing child to see with comfort. This has been alluded to by Dr. H. E. J. Biss (*Illuminating Engineer*, Vol. I, p. 190), and it is interesting to note that, by the advice of Mr. Brudenell Carter, *The Times* have recently decided to alter the nature of their smaller type.

The importance of this question to the nation will be understood from the fact that there are over 1,000,000 children in the schools of London alone. It is interesting to recall that Mr. Brudenell Carter, as far back as 1885, approached the School Board of London, and tried to induce them to organise periodical testing of the eyes of their children.

That Mr. Carter had ample grounds for urging this improvement will be understood from the decisive nature of the results of the tests of the German Professor Cohn, who in 1865 examined the eyes of about 10,000 school children and found that 1,630 of these had eyes of faulty shape, 1,072 being short-sighted, 139 flat eyed, 23 suffering from astigmatism, and 396 from the results of previous diseases. In addition, Mr. Carter's friend, Mr. Adams Frost, had examined a Board school in the South of London and found that 73 children out of 267, or rather more than one-fourth, suffered from defective vision. It was rational to conclude, therefore, that the possibility of equally bad conditions prevailing in other schools ought at least to be examined. On this occasion, as we have since had ample reason to regret, this recommendation was not complied with, but at the present day our views are more enlightened, and only last year it became obligatory for the London County Council for the first time to undertake periodical tests of this description.

But I feel constrained to point out that tests of eyesight alone are insufficient unless accompanied by some study of the conditions of illumination. It is no use studying a disease without also taking account of the conditions by which it was produced. In this connection it is satisfactory to note that Dr. Kerr, medical officer to the London County Council, made special reference to this matter in his report in 1908. I may quote the following words :—

"A normal person of middle-age will distinguish characters on paper in a poor light with greater readiness than a child, because the characters are more familiar to the adult and so much more easily recognised. Conversely, a child requires a better light to learn to read by than does an adult, to whom reading is second nature. From a large number of experiments, the least illumination permissible on the school desk of a child has been found to be equal to 10 candle-metres (*i.e.*, roughly 1 foot-candle)."

Dr. Kerr then studied the illumination in 165 schools, and found that the artificial illumination of about 20 per cent. was classed as only "fair," while 18 were considered "bad;" very similar figures were quoted of the daylight illumination.

In the report which has just been issued for the subsequent year stress is again laid on the part played by good illumination. Thus Dr. Woodcock points out that, apart from eye-troubles, nervous habits such as squinting, twitching of the eyebrows, &c., giving rise to a strained expression, are often the direct result of the close attention and effort involved in certain kinds of work (such as sewing) which impose a tax on the eyes. For instance, reference is made to a class of 28 children who

were hemming in a poorly-lighted room. A few minutes after work had commenced ten were squinting, eleven knitting their eyebrows, two standing up to sew, and half-way through the hour four children exhibited nervous defects. "Artificial light in schools" this observer goes on to remark "is practically always insufficient for this work" (*i.e.* fine work involving matching of colours and texture with precision). "From October to March," she says further, "no needlework should be allowed after 3 p.m., and during November 15th to February 15th no needlework should be permitted in the afternoon at all."

In this report Dr. Kerr again gives some figures relating to the conditions of illumination in various schools; they are as follows:—

QUALITY OF LIGHTING.

April 1st, 1907, to March 31st, 1908.

Non-Provided Schools—			
Good.....	57	65	per cent. approx.
Fair	10	11	„ „
Bad	21	24	„ „
Council Schools—			
Good.....	191	73	per cent. approx.
Fair	16 . ..	6	„ „
Bad	52	14	„ „

April 1st to December 31st, 1908.

Non-Provided Schools—			
Good.....	18	72	per cent. approx.
Fair	3	12	„ „
Bad	4	16	„ „
Council Schools—			
Good.....	237	81	per cent. approx.
Fair	23	8	„ „
Bad	33	11	„ „

Now, when the appointed authorities take the view explained above, it is sufficient to justify the contention that the study of the illumination in schools is a matter that deserves very careful attention indeed.

FACTORY AND BARRACK LIGHTING.

While dealing with the hygienic aspects of illumination, I may refer to the lighting of factories and barracks. Here again, although we are dealing mainly with adults, instead of children, we have a case of large numbers of people constantly at work under more or less stereotyped conditions. Think how many soldiers are constantly confined in barracks in this country.

I was given to understand that the War Office authorities were paying great attention to this subject, being desirous of adopting some definite plan for supervising the lighting in these cases, so as to render it in every way most efficient.

In the same way, it would seem to be a truism to say that good illumination in factories is not only absolutely essential to the workpeople, but expedient from the point of view of the employer. Good illumination, as I have tried to show, is not a luxury but a necessity, and therefore ought to be insisted upon every whit as keenly as the provision for adequate sanitation and ventilation, which, by the way, have only become the subject of Government inspection and recommendation (and in extreme cases even of prosecution) very recently. Why should an employer who confines his employees in a stuffy room be treated more severely than one who ruins their eyesight by grudging the necessary attention to lighting?

What may be pointed out in addition is that, even from the standpoint of the employer, it is folly to neglect this point. In the case of almost all skilled labour it is quite certain that the expense of bringing the lighting up to the standard is but a trifle in comparison with the amount that would be saved by the improvement both in quality and output of work; indeed, in many cases it is safe to say that such improvements as are needed would not really entail any greater running expenses, but only the exercise of a little forethought in using the light provided so as to help the workman instead of proving a nuisance to him.

But, in addition, there are obvious general grounds for dwelling on this point. Anyone who has been obliged to live for any length of time in dingy and badly lighted rooms knows the depressing effect of such surroundings.

Mr. Patchell, in his presidential address to the Association of the Engineers in Charge in 1908, remarked:—

"Good lighting is conducive to economy in both engine and boiler rooms, as plant in a badly lighted room never gets properly looked after or cleaned. Why should it? It is no credit to the cleaner if it cannot be seen. Dirt is about the worst disease a plant can suffer from, as it invariably means neglect of small indications and warnings, timely attention to which would prevent the otherwise inevitable breakdown. Not only is the plant better cared for, but men all work better in cheerful surroundings, and lose less time through sickness."

Another point on which stress may be laid is that a very close connection undoubtedly exists between the number of accidents that occur in works, and the condition of the lighting. Naturally, it is easier for an employee to allow a limb to stray into machinery which, in a

dingy ill-lighted room, is blurred and indistinct. In addition, the incorrect placing of light sources, and the resultant throwing of inconvenient shadows by tools is just as likely to be responsible for an error of judgment on the part of an operator engaged in a delicate piece of work.

At the present moment this matter is of particular interest in view of the Commission that has recently been appointed to consider causes of accidents in factories and workshops, and I should like to urge that no such inquiry can be considered complete that does not take into account the part doubtless played by defective illumination in causing accidents of this nature.

The report of the Chief Inspector of Factories for the year 1908 contains a number of pertinent comments on the effect of the lighting conditions on the health and well-being of operatives. It is gratifying to find one of the inspectors reporting that great advances have been made in the artificial lighting of factories; the same observer, however, remarks that the fact is not generally appreciated that the daylight-illumination requires corresponding care. A very striking case is that of laundries. It would seem fairly evident that where cleanliness is the great consideration, only the very best illumination can be deemed sufficient, and it is not surprising to find one of the inspectors, Miss Patterson, drawing attention to the effect of "crowding machinery into ill-lighted corners."

But, perhaps, the most interesting comment is that of Miss Squire, who referred to the defective illumination in certain Yorkshire textile factories, and the results of the trying work in a poor light on the eyesight of employees. Sometimes the suggestions of the inspectors recommending were welcomed and acted upon. "Sometimes, however," she says, "we are met with indifference or reluctance to spend money on this condition for healthy working, *and we have no statutory provision to rely upon.*"

The need of more definite recommendations regarding illumination, therefore, is now beginning to be felt. Reference may, in this connection, be made to a very interesting report of the Conseil d'Hygiène de la Seine in Paris on the subject of factory-lighting. As a communication from a municipal body this forms a somewhat important precedent. The report contains abstracts from the regulations of the chief European countries.

While not proposing any immediate drastic regulations the report emphatically endorses the wisdom of keeping all bright lights out of the field of view of workers and also advises that walls should be light in tint and have good reflecting qualities. It is interesting to observe that the only country, apparently, that prescribes definite minimum illumination is Holland, where an intensity of 10 to 15 bougie-metres on the work is specified (1 to 1·5 foot-candles approximately).

Lighting of Hospitals, Libraries, Churches, Etc.

Under this heading I may include a number of miscellaneous cases of lighting, all of which are of very great importance, but which, unfortunately, would require a lecture to themselves if treated fully. I may first point out the obvious necessity of lighting a *hospital*, where people in an invalid and depressed condition are confined with special care.

It is scarcely necessary to point out that people, under such circumstances are specially susceptible to the effect of unsatisfactory conditions of illumination, and trifling defects in the lighting arrangements, which a healthy individual might ignore, assume much greater importance in the case of people who are seriously unwell and possibly feverish. Anything in the least inclined to suggest a glare is most objectionable, and flickering and unsteady lights are particularly undesirable. One may also point out that the lighting of a ward in a hospital where patients in a convalescent stage are confined is probably governed by conditions quite distinct in many respects from those that should prevail in a room in which patients are seriously ill.

The daylight illumination provided is perhaps of special consequence, stress being laid by many in the medical profession on the part often played by sunlight in promoting a patient's recovery. For instance, at the request of the Westminster Hospital, an interim injunction was recently granted restricting the height of the adjacent new Wesleyan Memorial Hall now being built by the trustees of the Wesleyan Twentieth Century Fund. It was contended by the medical authorities that the proposed plan would interfere with the access of light to one portion of the hospital, and that the recovery of patients would be appreciably retarded thereby.

The necessity of paying careful attention to the light in *libraries*, where people use their eyes very severely, must also be borne in mind. This last matter is the more

urgent because the people who use libraries in the evening by artificial light are, as a rule, earnest students, the class of people who derive most benefit from libraries, and who, therefore, deserve the best artificial illumination that can be provided in order to facilitate their strenuous work.

Both libraries and hospitals frequently constitute an expense to the general public, who have a right to see that the best value is got for their money. The lighting of a number of such public buildings may in the aggregate amount to a considerable sum, and therefore it is only just that care should be taken not only to get efficient results, but also to exercise due economy.

A recently-issued report of the "Committee on Machinery and Engineering Staffs at Poor-law Institutions," which deals incidentally with the lighting conditions, well illustrates this point. The published figures for the lighting in question show remarkable variations, and the conclusion is drawn that greater care should be exercised in the control of the expenditure of gas and electricity than at present. Yet it must be recalled that many different varieties of buildings, which serve very distinct purposes, are grouped under this head, and it is, therefore, very difficult to draw any valid conclusion without knowing fuller details of the conditions in each case. One point may, however, be emphasised. It would well repay the authorities in such cases to obtain the advice of a competent expert when the original lighting scheme of a new building is under consideration. Experts called in at a later stage may, indeed, be able to effect a considerable saving; yet, when once the installation is complete, any modification must be in the nature of a compromise, and it is rarely possible to secure as efficient results as might have followed the original adoption of a carefully thought-out plan.

In this connection I should like to mention the work of Mr. L. B. Marks, a well-known illuminating engineer in the United States, and the first President of the Illuminating Engineering Society, who has recently undertaken and described the lighting of the Carnegie libraries in New York, in a specially careful manner (*Illuminating Engineer*, Vol. I., 1908, page 921). Here, again, I should like to point out the inconsistency of paying for the collection of expensive books, sometimes unique and unreplaceable, housing them in costly buildings, and then providing a system of illumination that makes reading more than a weariness of the flesh.

FIG. 83.

SECOND FLOOR, CARNEGIE LIBRARY IN NEW YORK. (L. B. Marks, Second Annual Convention of the Illuminating Engineering Society in the United States, 1908.)

And next, a few words may be said upon the lighting of churches and public buildings of architectural distinction. In such cases, economy and illuminating efficiency, in the technical sense, are often subservient to artistic effects. But once more we must remember that it is only through the eye, and through the illumination provided, whether daylight or artificial, that the interiors of such buildings are visible at all. Therefore it is surely worthy of consideration to scheme out the lighting very carefully, and to consider exactly what the sources used have or have not to do. This is a matter I commend to the study of architects, who are now coming to take a keener interest in questions of illumination.

The lighting of such national buildings as Westminster Abbey surely deserves very careful consideration indeed, and when we remember that they frequently fulfil several distinct purposes the choice of an effective method of illumination becomes correspondingly difficult. For instance, Westminster Abbey serves primarily as a religious building, but, being the treasury in which so many national monuments, &c., are stored, also partakes of the nature of a museum. And the lighting of our museums, if attempted artificially at all, surely demands the greatest care we can give it. For the exhibits can only make their appeal through the eye, and the eye only becomes aware of their existence by the aid of light. Naturally therefore one would suppose that the method of lighting specimens so as to show off their chief points to the best advantage would be very carefully thought out and as near as possible ideal for the purpose; it is doubtful whether this can often be said to be the case.

FIG. 84.

ROOF READING ROOM, CARNEGIE LIBRARY IN NEW YORK. (L. B. Marks, Second Annual Convention of the Illuminating Engineering Society in the United States, 1908.)

FIXTURE DESIGN.

This, again, is a very wide subject into which I cannot enter in detail. It will, however, be readily appreciated from what has been said already, that fixture-design offers great opportunities to the man who has not only a knowledge of the details of the best methods of distributing light efficiently, but also a genuine appreciation of artistic principles. There seems little doubt that a great many of the types of fixtures in general use at the present day leave something to be desired both from the æsthetic and practical standpoints, though great improvements have recently been made; in the United States in particular, the recent formation of the Illuminating Engineering Society has given a great

impetus to the scientific design of fixtures from the standpoint of practical efficiency. It is, however, often interesting to observe the care which was bestowed on the artistic design of sources of illumination in the past, which were certainly very primitive regarded from the practical standpoint as illuminating apparatus, but were not infrequently distinctly effective as ornaments.

It is also hardly necessary to dwell upon the importance of a knowledge of the particular varieties of fittings which are best adapted for use in certain interiors; the illuminating engineer, engaged on such work, needs to possess a considerable knowledge of art and architecture in order to contrive arrangements in harmony with the existing scheme of decoration.

An interesting point has been raised in a recent number of *The Builder*. The author criticises many of the existing electric light standards in the streets of London, and points out how illuminating apparatus of this kind, while at night mainly essential for the purpose of producing light, ought to be decorative by day when its main function is in abeyance. The engineer would often be grateful for guidance on the æsthetic principles involved in this question. Certainly the style of lamp-posts lining a street can do much to make or mar its architectural appearance, and ought to be in harmony with the style of buildings or surroundings.

Street Lighting.

The subject of street lighting received some attention in my second lecture (see p. 42), but this occasion may be taken of emphasising a few of the most important points in connection with the matter. Since the delivery of these lectures the writer has had an opportunity of visiting many of the chief continental cities and conversing with the chief engineers responsible for the street lighting, both gas and electric, therein. Many differences of opinion were met with but it was invariably agreed that the points in dispute among experts could be largely cleared up if only the different authorities interested could be got together to discuss the matter and determine in what good street lighting really consists. At present the criteria are extremely vague, what is regarded as eminently satisfactory in one city being tabooed in another.

Unfortunately it cannot be said that any really adequate effort has yet been made to distinguish between the purely local conditions which so often influence decisions on this matter and the general principles which are applicable to most cities. It is frequently supposed by those who do not appreciate the part which local conditions inevitably play in deciding such questions that because some city, Berlin for example, adopts incandescent high-pressure gas lighting after protracted tests comparing the results of this method with those obtainable by electric lighting, therefore the relative merits of both methods have been settled once and for all and that any other town in doubt as to the method of lighting to be adopted can profit by their lesson and do likewise.

In reality the decision of the authorities may be mainly influenced by facts quite outside the tests in question. In Berlin, for example, the gas-plant is owned by the municipality while the electricity supply company pay handsomely for the privilege of undertaking electric lighting. Now vast extensions to the present gas-generating plant have recently been made at Tegel near Berlin, and the authorities must naturally look to street lighting as a main outlet for the gas generated. It may in fact be said that every city has to find out for itself which method of lighting best meets local conditions.

Yet there is no reason why they should not derive useful information from properly organised experiments of other cities relating to matters which really can be settled by scientific experiment. But these experiments must be undertaken with a clear and definite idea of what it is desired to find out, and the results derived from them must be presented in such a way as to be free from confusion with the local influences referred to. And in order to be reliable such tests ought to be undertaken by an impartial and expert authority whose decision would carry weight. The writer long ago advocated the establishment of a central testing department for the purpose of undertaking genuine research into street lighting problems. The tests would be more valuable, even on the present lines, where they undertaken by representatives of gas and electric lighting conjointly and on a pre-arranged common plan. At present, what frequently happens is that a series of tests are undertaken by an expert in electric lighting, and another series, undertaken on quite different assumptions and under quite different conditions by a representative of gas lighting. Subsequently the results (being really not strictly comparable) are found to be at variance, and those connected with each system profess to distrust the tests of the other and to believe that he has

contrived a method of experiment which is specially favourable to his own illuminant. Were the experiments carried out by both representatives simultaneously, as explained above, much useless subsequent recrimination might be spared, and there would be more probability of our being able to draw some useful conclusions.

There is in some quarters an impression that street lighting is a simple matter which can be readily judged by ocular demonstration before a body of men having no technical knowledge of the matter. Apart from its other drawbacks, however, it is at least obvious that such methods must give rise to hopeless difference of opinion, and that the possibilities of such differences are accentuated by the fact that an opinion so based cannot be substantiated by reference to any record which would guarantee that the conditions existing when the impression was gained would be maintained subsequently. When our knowledge of the lighting in a street is based on photometric tests we can, at any subsequent period, repeat these tests in order to ascertain whether any change in the conditions has occurred. But when we merely depend on our recollection of what the lighting looked like on some past occasion, how is it possible to justify an impression that the light has deteriorated?

In addition, it is safe to say that ordinary people base their views on the lighting of a street on very different data. Many people, for instance, will be found to judge far more by the apparent brightness of the sources themselves than by the available illumination which they shed upon the roads and pavement. Nor is it to be expected that a man who has not really studied the problem can, by a mere visual impression, unsupported by any means of measurement, determine which of two alternative systems of lighting is best fitted to suit the complex demands of traffic, the needs of pedestrians, artistic appearance, and the other

FIG. 85.

SHOP WINDOW, RICHMOND, U.S.A. LIGHTED BY GAS; NIGHT VIEW (Welsbach Co.).

factors which have to be duly weighed in this matter.

In short, we need to form more definite views regarding what the object of street lighting should be, and better methods of expressing and measuring the requisite conditions. For this purpose photometry, as we now know it, is admittedly capable of improvement, and may in the future be supplemented by other tests. But it is certainly capable of preserving a record and yielding much valuable information unobtainable at present by any other means.

FIG. 86.

TOBACCO SHOP IN WASHINGTON, U.S.A, LIGHTED BY GAS. NIGHT VIEW.

SHOPWINDOW LIGHTING.

A word or two may be said on this interesting subject. There is, perhaps, scarcely any field where the principles of illuminating engineering can be more profitably employed. It is no exaggeration to say that one still cannot walk the streets of London, or indeed any city, without constantly meeting examples of light, not only unwisely, but actually uselessly employed.

We have seen previously how the interposition of a bright light causes the pupil-aperture and retina of the eye to react in such a manner that objects of a darker hue in the background become difficult to see, and how the eye is injuriously affected by continual exposure to glaring lights. Yet one frequently sees naked filaments placed in the window between the eye of the observer and the goods he is intended to observe by their light; frequently, too, the pedestrian is dazzled by a lavish use of intensely bright flame arc lamps, hung well within his field of vision round a shop-window; such lamps if not properly located are also a menace to traffic on account of their inconvenience to drivers. It is satisfactory to observe that regulations have recently been introduced in the City of London, forbidding the use of such lamps unscreened towards the roadway.

Such malpractices ignore the wise motto, "Light on the object, not in the eye." To be successful, any method of shopwindow lighting must be at least comfortable to the eyes. A window may well be likened to a miniature stage. The use of bright lights has been defended on the ground that it is necessary to

be lavish in this respect to attract custom. Excessive glare may, indeed, attract the eye involuntarily, but it is questionable whether anything is gained thereby, as the observer naturally tends to avert his gaze from anything actually distressing.

the sign "Cigars"; this is a device which is now becoming very popular.

In Fig. 88 will be seen a means of applying this method by the aid of flame arc lamps, which are placed above a diffusing glass surface over the goods, and can be drawn

Fig. 87.

Shop Window of Carpet Store Illuminated by Means of Reflex Gaslights. (Welsbach Co.)

The most successful methods of shop lighting seem to be those in which the lessons of the stage are taken to heart, abundant light being shed upon the goods while the actual sources themselves are screened from the eye of the observer. Some examples of this method are shown in Figs. 85 and 86.

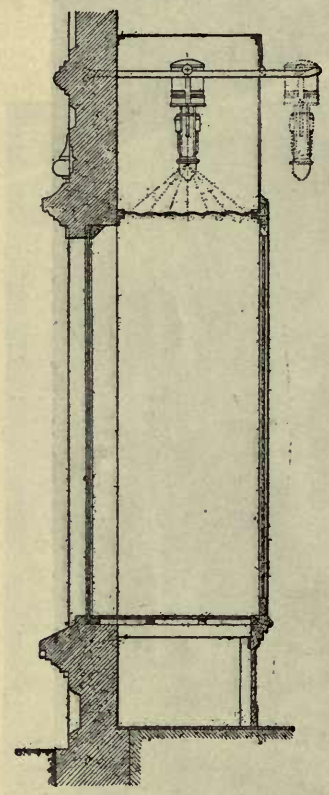
In Fig. 86 it will be observed that the same lights which, concealed, illuminate the contents of the window, are also utilised to illuminate aside to be attended to, when necessary, as shown in the illustration.

Apart from these obvious rules of good lighting there are, of course, endless possibilities in the direction of achieving special effects by the use of light, and these afford great scope for artistic treatment. In some of the best shops arrangements are made enabling several alternate methods of lighting to be used, a change in the contents of the window

being accompanied by a change to the method of illumination best adapted to display them to the best advantage.

In this connection it may be of interest to point out that a change in the motives of window-display, first perceived in the United States, seems to have been making itself felt also in this country of late. In many shops the window display is regarded mainly as an

FIG. 88.



SHOWING ARRANGEMENT ENABLING FLAME ARC USED FOR SHOP-WINDOW LIGHT TO BE CONCEALED FROM VIEW AND DRAWN ASIDE TO RECEIVE ATTENTION WHEN NEEDED.

inventory, as complete as possible, of the goods kept in stock. The customer is expected to make up his mind what he wants by inspection of the window, enter, and ask for this article. This naturally involves crowding the windows and makes effective lighting methods difficult to achieve. Now, however, perhaps especially in the United States, it is becoming felt a tasteful shop-window should be mainly devoted to novel and specially interesting goods, so that the passers-by may come to regard its contents, not as a catalogue, but as a summary of the most recent developments; this leads him to look to the window for novelties and not to pass it by, assuming by the force of habit that it contained nothing new. He would, therefore, no longer be expected to make up his mind as to his requirements before entering, but would be induced to do so whilst yet undecided as to whether he meant to purchase, and would be prepared to entertain suggestions and assistance from the shopman on the subject of what he needs. It is possible that this newer attitude towards window-dressing may have a beneficial influence on the methods of lighting employed.

STAGE LIGHTING.

There is, perhaps, no subject which presents better opportunities for successful co-operation between the illuminating engineer, with a knowledge of the best means of producing and using light, and the artist with his trained perception of what is most beautiful, than that of stage lighting.

It is not only that the general method of illumination employed in a theatre is of very vital importance; in any entertainment in which an appeal is made to the eye it is, of course, essential that there should be nothing distressing or distracting in the illumination provided for the benefit of the audience. But the success of many theatrical pieces and operas is so closely connected with the impression received through the eyes, that the illumination of the stage itself must require not only specialised knowledge of technical details, but also, in an exceptional degree, fine perceptions and artistic sensibility. In operas, for instance, one can readily understand that the scheme of lighting should produce an effect parallel to and in harmony with that produced by the music. The most artistic scenery, again, would be diminished in effectiveness by a choice of a method of lighting which interfered with the proper colour relations. There are also numberless theatrical devices, such as the simulation of flowing molten metal, the production of sparks between clashing swords, apparitions, and so forth which offer great scope to the ingenuity of the engineer in charge of the lighting of the stage.

While it may be justly said that the arrangements at our best theatres often reflect very great credit on those responsible for the stage lighting arrangements, it seems quite reasonable to suppose that in this subject special benefit might follow a closer co-operation between the illuminating engineer, the artist, and the other specialists whose views have a more or less direct bearing on the subject.

Lighthouse Illumination, &c.

The provision of proper means of illumination round sea coasts, for the indication of waterways and channels, and for purposes of navigation generally, is, of course, a matter of international importance, and one on which the concerted action of different nations is particularly to be desired. The wideness of the subject, which demands peculiar expert knowledge, is well illustrated by the annual report issued by the Lighthouse Board of the United States.

I cannot discuss this important subject in any detail on this occasion. It may, however, be said that it is one which the illuminating engineer should find of special interest, and in connection with which he may, in the future, render valuable service, because it involves the consideration of the merits of the different illuminants in an impartial manner.

Those who wish for fuller information may be recommended to study the report of the Royal Commission, which was issued last year, relating to the lighting of the shores of Great Britain and Ireland.

Some Physiological Effects of Different Qualities of Light.

I may next make a few remarks upon another feature of artificial lights of the present day which seem to require study. I have already drawn your attention to the difference in the colour of light yielded by modern sources. Now we have no precedent to enable us to determine what may be the effect of very peculiar coloured light in any quantity on the eye, though there is scientific work on record which suggests that visible light from different parts of the spectrum produces diverse physiological effects. Therefore one would certainly recommend that we should be cautious in seeking to work for long hours under any peculiar variety of light. Professor Burch, in the work previously referred to, has dwelt upon the disturbances of colour vision which may be called into play through intense stimulation of the eye by monochromatic light, and it is therefore legitimate to sugest that prolonged working under light of one colour might eventually affect the eyes in some such way.

Meantime it is interesting to observe that there seems to exist some prejudice in favour of light of a more or less golden colour as compared with the whiter tinge of the most recent illuminants. The explanation of this preference offers very debatable ground for discussion. Some authorities have maintained that light from the red end of the spectrum has an actual stimulating physiological effect, while blue and green light, on the other hand, are depressing. Others have sought to show that a preference for yellowish light is merely a matter of association. From the early camp fires onwards our sources of light and heat have come to be associated with red and yellow shades of colour, and we involuntarily connect this view with the warmth and brightness within as opposed to the blue shades of twilight and the coldness without.

It seems quite conceivable that the radiation from the different portions of the spectrum, which we are accustomed to consider mainly in connection with its illuminating capacity, may also be responsible for deep-seated physiological effects and influence our health and well-being to a very considerable extent. And, leaving out of account for the moment the possible special effects of visible light of different colours, we must also remember that our present illuminants radiate a wide range of invisible waves, which are not detected by our eyes as light but which may, nevertheless, not be without influence upon our physiological condition. Recently a number of facts have been discovered about the behaviour of the so-called actinic or ultra-violet rays (beyond the violet in the visible spectrum), which have led physiologists and physicists to attach some importance to their presence, to some extent, in all illuminants. With this matter we shall deal in some detail later.

For the moment, however, let us turn our attention to what is known regarding the quality of radiation from different illuminants, and the manner in which the energy is distributed throughout the visible and invisible spectrum. This quality, we shall find, exerts a very material influence on the efficiency of light-production of the different sources.

The Distribution of Energy in the Spectra of Illuminants and the Efficiency of Light-Production.

In what follows, therefore, I wish to proceed to consider some of the scientific theories of light production. It has long been believed that the majority of sources of light, considered from the scientific standpoint, are hopelessly inefficient, producing but a small fraction of the energy supplied to them in the form of light. For instance, the percentage of the energy developed by electric glow-lamps in a visible form has been variously stated as

TABLE IV.

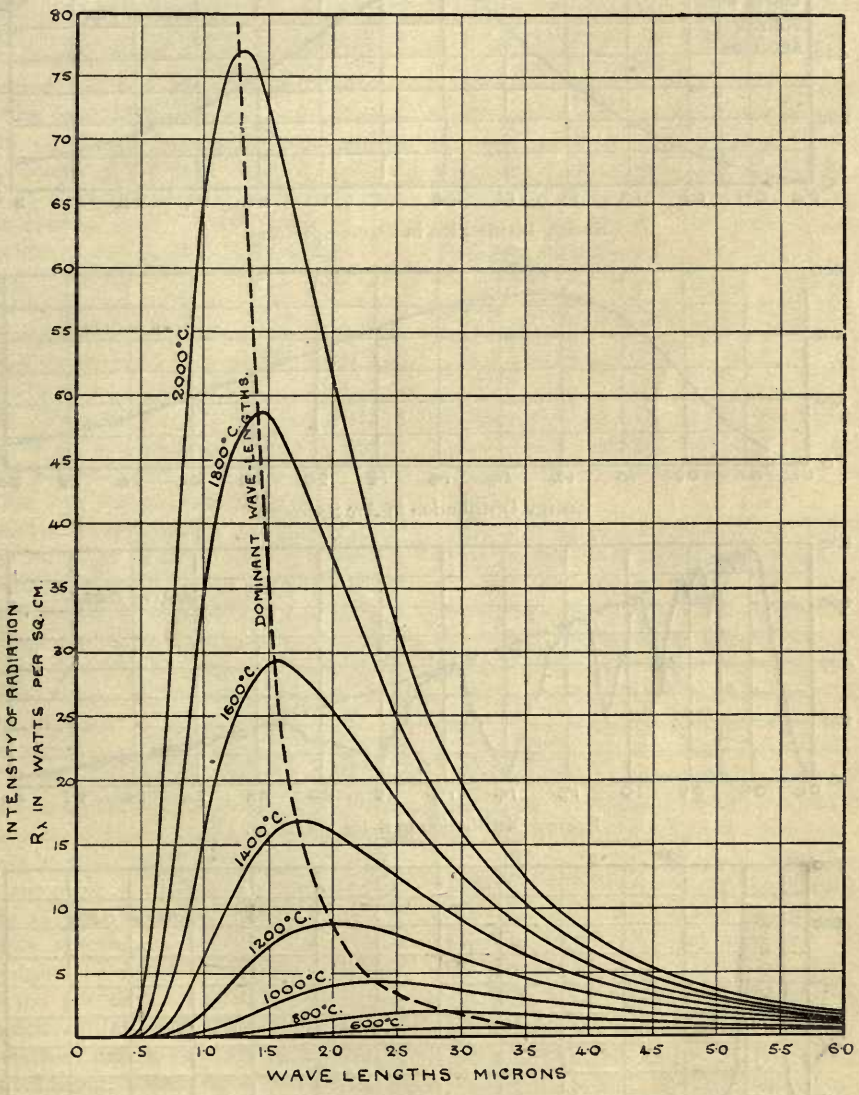
LUMINOUS EFFICIENCIES OF VARIOUS SOURCES (Drysdale, the *Illuminating Engineer*, June, 1908).

Source.	Observer.	Date.	Method.	Total Efficiency. Per cent.	Radiant Efficiency. Per cent.
Candle	Thomsen	1863	A	0·3	2·1
Oil Flame	Melloni	1833	A		10
	Thomsen	1863	A		2·06 to 2·11
	Wedding	1905	A		0·029
	Lux	1907	A	0·25	1·23
Hefner Lamp	Lux	1907	A	0·103	0·89
Gas flame	Tyndall	1862	A		4
	Thomsen	1863	A		1·84 to 2·11
Incandescent Gas	Lux	1907	A	0·46 to 0·51	2·03 to 2·97
Acetylene Flame	Angstrom	1902	A		5·6
	Nichols and Coblentz	1903	C		3·3 to 4
	G. W. Stewart	1902	C		4
	Lux	1907	A	0·65	6·36
Glow Lamp					
Incandescent	Melloni	1833	A		2
Platinum	Tyndall	1862	A		4·17
Carbon Filament	Merritt	1889	B	·5 to 7·2	
	Russner	1907	B	·58 to ·61	
	Wedding	1905	A		0·34
	Lux	1907	A	2·07	2·7 to 3·2
Nernst	Ingersoll	1903	C		4·7 falling to 3·6
	Wedding	1905	A		0·85
	Lux	1907	A	3·85 to 4·21	5·7
Tantalum	Russner	1907	B	2·2	
	Lux	1907	A	4·87	8·5
Osmium	Russner	1907	B	2·3	
	Wedding	1905	A		0·62
Osram	Russner	1907	B	2·46	
	Lux	1907	A	5·36	9·1
Arc Lamp	Tyndall	1862	A		10 to 11
	Tyndall	1862	C		7·7
	Nakano	1889	A		1·48 to 8·1 various angles.
	Marks	..	..		2·3 to 16·2
	Wedding	1905	A		0·318
D.C. Arc	Lux	1907	A	5·6	8·1
D.C. enclosed Arc	Lux	1907	A	1·16	2·0
Flame Arc, yellow	Lux	1907	A	13·20	15·7
Flame Arc, white	Lux	1907	A	6·66	7·6
A.C. Arc	Lux	1907	A	1·9	3·7
Mercury Arc	Geer	1903	A		40·8 to 47·9
Uviol Mercury, Vapour	Lux	1907	A	2·24	5·8
Quartz Lamp	Lux	1907	A	6·00	17·6
Vacuum Tube	Drew	1903	A		23·4 to 48·6

being only about from 1 to 10 per cent., all the rest being produced as heat or other forms of energy which are non-luminous.

As explained in my first lecture, the majority of our illuminants consist of incandescent solids. We merely heat up a solid body until, amid the jumble of vibrations that occur, we find a few sufficiently rapid to emit light. One interesting quality of incandescent solids is illustrated by Kirchoff's law, which states that every body emits only that radiation which it can absorb. According to this view a *truly black body*, which absorbs all the energy falling upon it, can naturally emit all forms of energy. Most of our incandescent solids resemble a black body somewhat closely, and therefore the curves describing the quality of radiation obtained from such bodies at different temperatures, according to Lummer and Pringsheim, are of considerable interest. Fig. 89, which is taken from a recent article by Dr. Drysdale in the *Illuminating Engineer*, shows these curves. I cannot, on this occasion, enter into the methods by the aid of which the

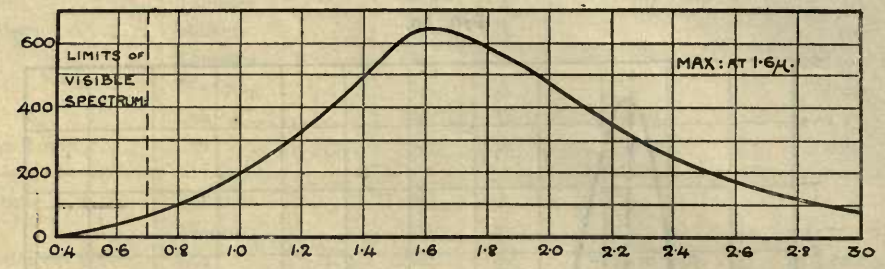
FIG. 89.



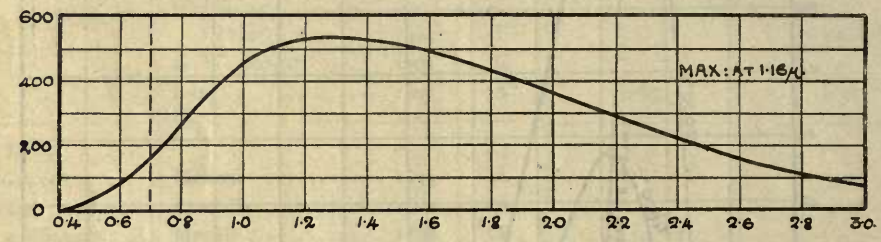
CURVES OF RADIATION FOR BLOCK BODY.
(*See* Drysdale, *Illuminating Engineer*, London, Vol. II., 1909, p. 231.)

energy in any part of the spectrum can be measured. Most of these methods depend upon the reception and absorption of such energy upon a blackened surface; the rise in radiation lying within the visible spectrum increases also very markedly, and hence our efficiency increases; Dr. Drysdale has recently calculated that the luminous efficiency

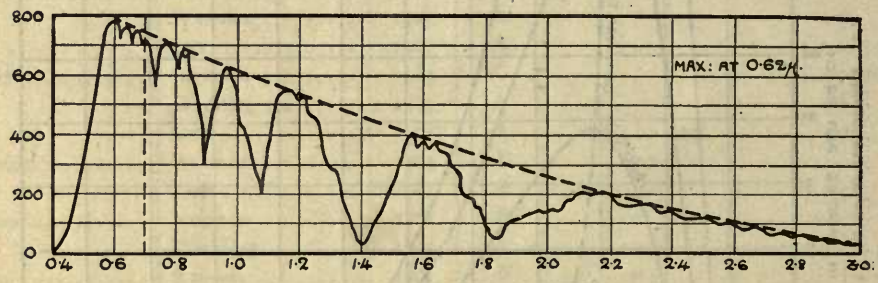
FIG. 90.



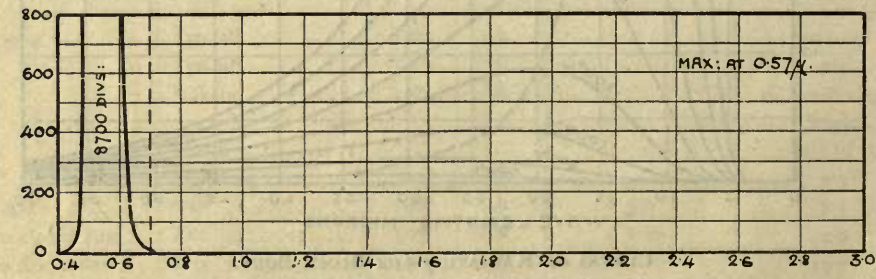
Energy Distribution in Flame Spectrum.



Energy Distribution in Arc Spectrum.



Energy Distribution in Solar Spectrum.



Energy Distribution in Firefly Spectrum.

LANGLEY'S CURVES OF RADIATION. (Drysdale, *Illuminating Engineer*, London, Vol. II., Jan. 1909.)

temperature of this surface may be taken as a measure of the energy impinging upon it and is recorded by suitable means, usually thermo-electric. You will, however, see that as the temperature increases the percentage of the even of an incandescent black body might attain 50 per cent. at the enormous temperature of 7,000°. Naturally, we can hardly hope to approach this temperature in any of our ordinary illuminants, and, therefore, the effi-

ciency as a light-producer is usually very low. The curves in Fig. 90, for instance, show the distribution of radiation in the case of a flame, the arc light, and the sun, as determined by the American physicist, Dr. S. P. Langley, and recently presented by Dr. Drysdale in the articles referred to above. Only in the case of the sun does the maximum fall within the visible spectrum; the majority of energy even then is waste, as far as luminous impression is concerned. It will, however, be perceived that in the case of the firefly a very different condition of things occurs, all the energy being concentrated within the visible range.

This has been suggested by some observers to be a curious property of fluorescent and phosphorescent substances, and leads us to hope that a really efficient light might be produced by this means in the future.

The mention of phosphorescence leads me to speak of an alternative method of increasing efficiency besides increasing the temperature of a body. Instead of employing the confused vibration of an incandescent solid, in which the whole mass vibrates as a whole, we may employ the free natural vibrations of a phosphorescent or "luminescent" substance.

Theoretically, as we have seen, it might be considered with some reason that the ideal illuminant would be one which produced a curve of spectral intensity identical with that of average daylight, but entirely confined to the visible range of vibration. Could we, therefore, discover a substance the natural vibration of which corresponded exactly to this state of things we should consider ourselves on the way towards solving our problem. Even the above assumption, however, may perhaps ultimately be found to require modification.

From one point of view an illuminant which produces all the rays just as they exist in the visible spectrum of daylight, and these only, might be said to have an efficiency of 100 per cent. But since the luminous efficiency of different parts of the spectrum itself differs very much, the maximum effect being, according to some authorities, produced in the yellow-green, it might be possible, by sacrificing colour, to receive yet greater efficiency. For certain purposes, in a lighthouse, for instance, it is obvious that correct colour appearance is immaterial; *brightness* is what we chiefly want. Therefore one might recommend the attempt thus to specialise in the most efficient light for certain special purposes.

Yet even this recommendation wants modification, because it is evident that all such statements are affected by the physiological peculiarities of the eye. Without entering further into this question it may be said that according to some authorities the behaviour of the eye seems to be profoundly altered when the illumination is very low; therefore the light, which is most efficient under ordinary circumstances, may not be the most serviceable under these altered conditions.

Many investigators have sought to determine what would be the theoretical efficiency possible in the case of an approximately white light, supposing that we were able to exclude all the wasteful non-luminous radiation and to produce only luminous energy. According to Dr. C. V. Drysdale, for instance ("Proc. Roy. Soc.," Vol. 80, 1907), it should be possible theoretically to obtain a white source running at only 0·08 watts per candle, and a monochromatic yellow-green source consuming only 0·0598 watts per candle. This, of course, would be a great advance on the best of our present metallic filament electric lamps which probably cannot, as yet, be commercially used at less than about 1 watt per candle.

Yet it must be said that different observers have obtained very divergent numerical results on this question as yet. The theoretical efficiencies possible, on the assumption that only light energy is produced, according to Lux, Wedding, and others, are widely different, in many cases, from the figures mentioned above; we should probably act wisely in postponing judgment on this point until more complete data are available. Very possibly these values will be found to be largely dependent on the physiological conditions of the eye. For instance, Mr. J. S. Dow has suggested that, on account of the physiological phenomena alluded to above, the values of the maximum efficiency, for light of different colours, may be found to be very different at high and low illuminations, and may also be affected by the region of the retina in the eye used in making the determinations (*Electrical World*, N.Y., Dec. 12th, 1908).

Unfortunately, most luminescent substances at present display inclinations to radiate in an irregular manner, and to produce light of certain wave lengths only; thus a source like the mercury vapour lamp, or the flame arc, usually radiates very strongly in certain parts of the spectrum, while other portions are correspondingly weak. In the mercury light, for example, the red rays are entirely absent. Many flame arcs again owe their efficiency

partly to the production of a very strong peak in the yellow, where the sensitiveness of the eye to visible light is believed to be a maximum.

Naturally, such sources as these cause considerable colour distortion in the coloured materials on which they impinge; even sources, however, which yield a continuous spectrum, differ very much in the strength of the radiation in different parts, and therefore differ in the appearance of coloured objects to which they give rise.

Table V., obtained by G. H. Stickney (Illum. Eng. Soc. 1908), illustrates the appearance of objects of various colours seen under the light of various illuminants.

TABLE V.

COLOUR VALUES OF ARTIFICIAL ILLUMINANTS.—By G. H. Stickney.

"Transactions" of the Illuminating Engineering Society (American), May, 1907, p. 282.

The Effect of Coloured Lights on Aniline Dyed Materials.

From Tests by M. Chevreul at the Gobelin Tapestry Works. With Additions by W. D'A. Ryan.

Orange	rays	falling on	white	make it	appear	orange.
,,	,,	,,	red	,,	,,	reddish-orange.
,,	,,	,,	orange	,,	,,	deeper orange.
,,	,,	,,	yellow	,,	,,	orange-yellow.
,,	,,	,,	green	,,	,,	dark yellow-green.
,,	,,	,,	blue	,,	,,	dark reddish-grey.
,,	,,	,,	violet	,,	,,	dark purplish-grey.
,,	,,	,,	black	,,	,,	brownish-black.
Red	,,	,,	white	,,	,,	red
,,	,,	,,	red	,,	,,	deeper red
,,	,,	,,	orange	,,	,,	orange-red.
,,	,,	,,	yellow	,,	,,	orange.
,,	,,	,,	green	,,	,,	yellowish-grey.
,,	,,	,,	blue	,,	,,	violet.
,,	,,	,,	violet	,,	,,	purple.
,,	,,	,,	black	,,	,,	rusty-black.
Yellow	rays	falling on	white	make it	appear	yellow.
,,	,,	,,	red	,,	,,	orange-brown.
,,	,,	,,	orange	,,	,,	orange-yellow.
,,	,,	,,	yellow	,,	,,	deeper yellow.
,,	,,	,,	green	,,	,,	yellowish-green.
,,	,,	,,	blue	,,	,,	slaty-grey.
,,	,,	,,	violet	,,	,,	purplish-grey.
,,	,,	,,	black	,,	,,	olive-black.
Green	,,	,,	white	,,	,,	green.
,,	,,	,,	red	,,	,,	yellowish-brown.
,,	,,	,,	orange	,,	,,	greyish-leaf-green.
,,	,,	,,	yellow	,,	,,	yellowish-green.
,,	,,	,,	green	,,	,,	deeper-green.
,,	,,	,,	blue	,,	,,	bluish-green.
,,	,,	,,	violet	,,	,,	bluish-grey.
,,	,,	,,	black	,,	,,	dark greenish-grey.
Blue	,,	,,	white	,,	,,	blue.
,,	,,	,,	red	,,	,,	purple.
,,	,,	,,	orange	,,	,,	plum-brown.
,,	,,	,,	yellow	,,	,,	yellowish-grey.
,,	,,	,,	green	,,	,,	bluish-green.
,,	,,	,,	blue	,,	,,	deeper-blue.
,,	,,	,,	violet	,,	,,	deep bluish-violet.
,,	,,	,,	black	,,	,,	bluish-black.
Violet	,,	,,	white	,,	,,	violet.
,,	,,	,,	red	,,	,,	purple.
,,	,,	,,	orange	,,	,,	reddish-grey.
,,	,,	,,	yellow	,,	,,	purplish-grey.
,,	,,	,,	green	,,	,,	bluish-grey.
,,	,,	,,	blue	,,	,,	bluish-violet.
,,	,,	,,	violet	,,	,,	deeper-violet.
,,	,,	,,	black	,,	,,	violet-black.

Colour Values of Artificial Illuminants.—(continued).

PREDOMINATING COLOUR OF ARTIFICIAL LIGHTS.

Lamp.	Colour.
Enclosed arc—clear globes	Bluish-white.
Enclosed arc—opal globe and selective diffuser	White.
3½ amp. 140 volt d.c. enc. arc.	Violet (beyond colour correction).
Nernst lamp—new glower	Pale lemon-yellow.
Nernst lamp—seasoned glower	Deep lemon-yellow.
Incandescent—new	Yellow.
Incandescent—seasoned	Pale orange-yellow.
Welsbach and vapour hydrocarbon—new	Greenish-white.
Welsbach and vapour hydrocarbon—seasoned	Greenish-yellow.
Ordinary gas flame	Reddish-yellow.
Mercury arc lamp	Blue-green.

It may be suggested that a Table of this kind might well be of considerable interest to decorators, architects, and others engaged in problems connected with colour-effects in interiors. As was pointed out before, the choice of the colour of wall-papers, &c., in an interior is a matter which has a very considerable effect upon the conditions of illumination, and should not be settled quite apart from the spectrum of the illuminant to be used. It is also not so easy invariably to foretell how an object of some particular shade may appear when viewed by means of a different illuminant from that under which it is first seen and purchased; and, as mentioned previously, even the surroundings are not without influence in determining the colour of objects seen in an interior.

There is also a need for some form of instrument which can readily be applied to compare the spectra of different illuminants, and in this connection the "Ives colorimeter," which was described at the second annual convention of the Illuminating Engineering Society in the United States last year, is of considerable interest.

ULTRA-VIOLET LIGHT AND THE PHYSIOLOGICAL EFFECTS PRODUCED BY IT.

Apart from the effect of visible light, however—and it has been shown that artificial illuminants differ very markedly in this respect—the distribution of energy in the spectrum of illuminants varies yet more greatly, as the curve exhibited in Fig. 90 very clearly illustrates. Therefore we are naturally inclined to wonder what effect, if any, such changes in the character of the light we live under might have upon us.

This leads me to speak of a very interesting question that has recently been the subject of much discussion, namely, the effect on sight of the invisible rays of very short wave length beyond the violet in the spectrum of artificial illuminants. We have seen how, as the temperature of an incandescent solid body increases, the maximum of the curve of radiation is shifted forward towards the blue in the spectrum, so that the percentage of ultra-violet energy is distinctly increased. Now these rays appear to exert very marked physiological and chemical actions, and it has therefore been the subject of consideration how far the tendency towards accentuating them might be injurious.

Apart from this tendency of a part of incandescent solid substances, we have now at our disposal sources such as some types of arc lamps, and the quartz tube mercury vapour lamp, which are particularly rich in such radiation, and are, therefore, claimed to be specially serviceable for particular purposes, such as the destruction of bacteria, the treatment of leather, and for photographic and medical purposes. One very interesting example of the use of the Uviol lamp I may mention in passing. It is now believed that the fading of colours is largely due to the effect of ultra-violet light and the chemical action of rays of short wave length in the spectrum of the sun. Carpet manufacturers in the north of Germany used formerly to have to send their goods down south, where sunshine was more abundant, in order to test the permanence of their colours. Now, however, that a source so rich in ultra-violet light is available, they can test goods by the light of this lamp in a mere fraction of the time which was formerly necessary, and independently of climatic conditions.

The percentage of ultra-violet energy in ordinary incandescent illuminating agents is believed to be relatively small, possibly not more than a fraction of a per cent., but, on the other hand, it has been suggested that as much

as 30 per cent. of the total energy radiated from the mercury quartz tube lamp is available in this form. Naturally, therefore, special precautions have to be taken to avoid such sources having an injurious action on the eyes of anyone using them.

That a small change in the quality of radiation may eventually cause the eyes inconvenience is shown by the experiences of travellers in the snowy regions and at high altitudes where the atmosphere is not sufficiently dense to absorb the ultra-violet rays in daylight so effectively as on the horizon. Snow blindness, and the tanning of the skin are well-known symptoms at high altitudes, which many observers have attributed to the effect of ultra-violet rays.

A considerable amount of work has been done on this subject by Drs. Schanz and Stockhausen, in Germany. These observers have suggested that artificial light is invariably more wearisome to the eye than daylight, and regard the tendency towards accentuating the ultra-violet in ordinary illuminants as undesirable. In support of their contention these workers have quoted the results of Widmarck and others, who found that by concentrating ultra-violet light on the eye-lens a turbidity was set up, and the lens subsequently became semi-opaque. It has even been suggested that cataract is at least partially due to the action of these rays, and the well-known predominance of this defect among glass workers has been ascribed by some to the rays given out by the glowing material. This is now being made the subject of investigation by a special commission of the Royal Society appointed for the purpose. See Dr. J. H. Parsons, "The Deleterious Effects of Bright Light on the Eyes," *Science Progress*, July, 1909).

Drs. Schanz and Stockhausen have studied the effect of different ranges of ultra-violet light, dividing them into three classes, as shown in Table VI.

They point out further that ordinary glass absorbs the rays from 0·5 μ onwards, but allows those between 0·4 μ and this value, to be transmitted unchecked, and have further devised a special variety of glass—which they term "Euphos"—for the purpose of absorbing these defective rays. Some samples of this glass, by the kindness of the inventors, I am able to show to-night, I believe, for the first time in England. Here, for instance, are a few specimens of chimneys and lamp bulbs made of the glass. For this glass, the authors claim that, although the ultra-violet radiation is so effectively absorbed, only a small proportion of the visible radiation is lost.

TABLE VI.

ACTION OF ULTRA-VIOLET LIGHT UPON THE EYE.

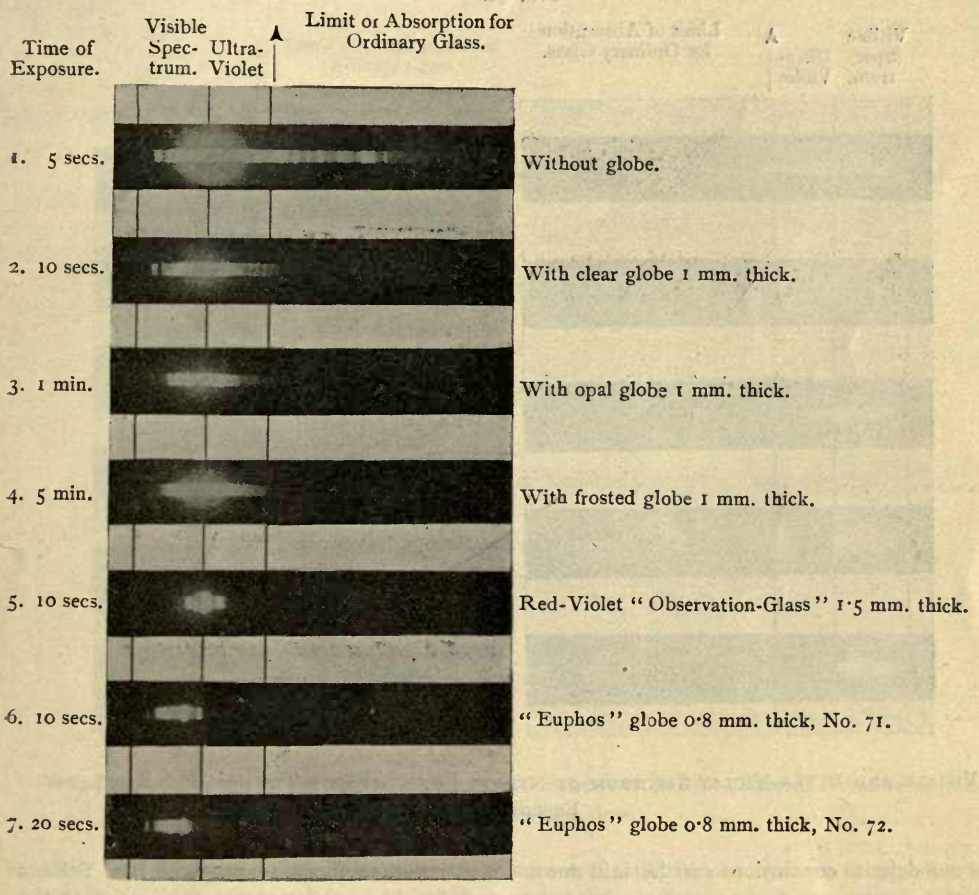
I.	II.	III.	IV.
760-400 $\mu\mu$.	400-350 $\mu\mu$.	350-300 $\mu\mu$.	300-0 $\mu\mu$.
Visible Rays.	Ultra-Violet Rays.	Ultra-Violet Rays.	Ultra-Violet Rays.
Reach the retina unaltered in character.	Cause the lens to fluoresce a lavender-grey, reach the retina, and are visible if the lens is removed, or if the visible region of the spectrum is suppressed.	Penetrate the eye, but do not reach the retina. Also absorbed by the eye-lens.	Do not penetrate, but cause inflammation of the outer eye.

Fig. 91, 92, and 93, which exhibit some spectrographs of illuminants illustrating the behaviour of the glass, do not require much explanation. It will be seen that the effect of the introduction of the Euphos glass is to cut off the ultra-violet light sharply, but to allow the visible light to pass, even up to the violet, with comparative ease. The various spectra also make it clear that the presence of an appreciable ultra-violet element is to be traced in most of the most recent illuminants. Ordinary glass, it will be observed, cuts off the extreme ultra-violet rays, but yet allows those which Drs. Schanz and Stockhausen consider to be the most dangerous to pass.

I will next perform a few simple experiments illustrating these points. The spectrum of an arc light is thrown upon the screen, the usual gradation of visible energy from red to violet being clearly discernible. But if now I introduce a screen made of barium platino-cyanide into the invisible portion of the spectrum out

beyond the ultra violet, the existence of these rays is made evident by vivid green fluorescence. We now see the spectrum extending far beyond the usual violet limit, but these remote rays can only be made visible by the aid of some such fluorescent material. In the beam of light striking the prism and giving rise to the spectrum, I now introduce a slab of blue Uviol glass. This glass has the property beam, the fluorescence disappears, indicating that the ultra-violet rays have been checked. A piece of ordinary blue window glass, on the other hand, behaves in an exactly opposite manner. That is to say, when introduced in the path of visible light it throws a very dark shadow. Placed in the path of ultra-violet light, on the other hand, it gives rise to practically no shadow at all. In the same way,

FIG. 91.


Time of Exposure.
Visible Spec- trum.
Ultra- Violet
Limit of Absorption for Ordinary Glass.
1. 5 secs.
Without globe.
2. 10 secs.
With clear globe 1 mm. thick.
3. 1 min.
With opal globe 1 mm. thick.
4. 5 min.
With frosted globe 1 mm. thick.
5. 10 secs.
Red-Violet "Observation-Glass" 1·5 mm. thick.
6. 10 secs.
"Euphos" globe 0·8 mm. thick, No. 71.
7. 20 secs.
"Euphos" globe 0·8 mm. thick, No. 72.

ELECTRIC ARC LAMP, VISIBLE AND ULTRA-VIOLET SPECTRUM AND EFFECT OF EUPHOS GLASS.

of stopping nearly all but the violet and ultra-violet rays. The violet is now the only portion of the visible spectrum which can be even imperfectly seen, but the introduction of the sensitive screen or a block of Uranium glass gives rise to the characteristic green fluorescence.

But if I now insert a sheet of the Euphos glass, which you will observe is practically transparent to visible light, in front of the electric lamp bulbs and chimneys composed of ordinary glass appear highly transparent to ultra-violet rays, and do not throw any distinct shadow on the fluorescent screen, while those composed of the Euphos glass appear very opaque, and give rise to a sharply-defined shadow.

I have dwelt at some length upon this question, not because I wish to over-emphasise its importance, but because it is typical of

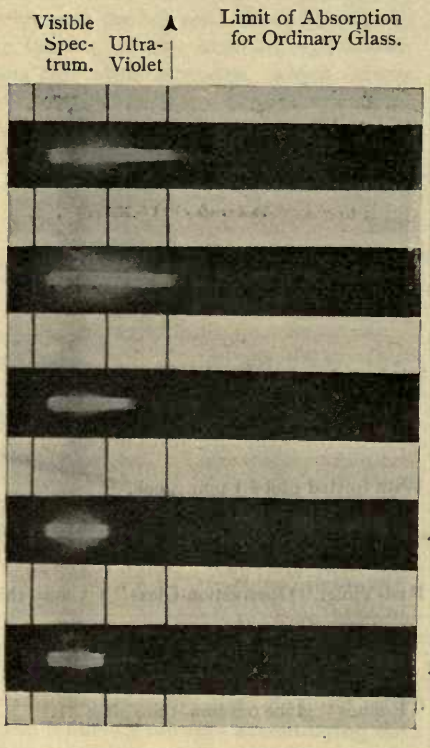
many that will crop up in the future, and is one that can only be effectively solved by co-operation between the physicists and the physiologists. In this respect, whatever opinions we may hold as to the validity of their conclusions, the researches of Drs. Schanz and Stockhausen seem to be particularly wort hy of imitation. Before leaving the subject, however, it is only fair to say that this matter is still the subject of investigation, and that no definite conclusions can be laid down as yet.

Among those who have differed from the two authorities referred to, I may mention Dr. W. Voege, of Hamburg, who has contributed several interesting communications to the *Illuminating Engineer*, stating his own view of the question (Vol. I., p. 775; Vol. II., p. 205).

I have made special reference to this subject simply with the object, as I say, of showing how the effective co-operation between physicists and the physiologists may lead to very valuable results. As an illustration, however, that I am not alone in wishing to draw attention to the matter, I may mention that this very question formed the subject of a most animated discussion before the German Institution of Electrical Engineers, at their annual meeting at Erfurt last year, and I think it is a remarkable recognition of the importance of these physiological questions that a purely engineering society should devote so much time to the subject. In addition, I may mention that the researches of Drs. Schanz and Stockhausen were communicated at the annual meetings of "oculists and others interested in physiological and natural science," (a very important body in Germany), in 1907 and 1908, and this too was an important recognition by the physiological authorities.

Whatever opinion we may hold as to the desirability or need of limiting the ultra-violet constituent in artificial illuminants, used under practical conditions, it will be conceded that when the eyes are exposed to exceptionally powerful doses of ultra-violet energy—in the

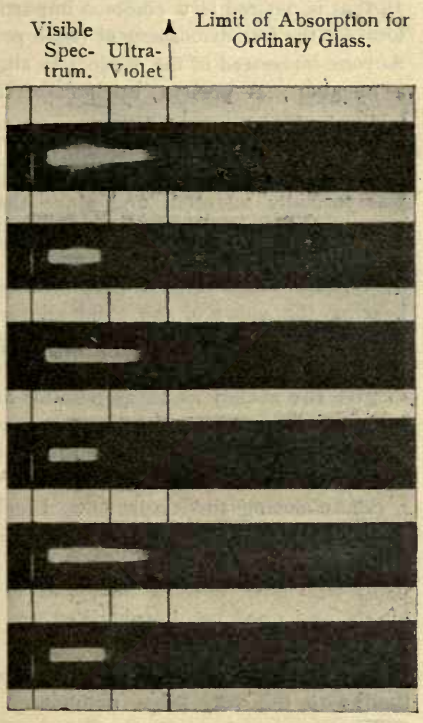
FIG. 92.


Visible Spec- trum.
Ultra- Violet
Limit of Absorption for Ordinary Glass.
1. Without globe.
2. With clear globe.
3. With opal globe.
4. "Euphos" globe, No. 71.
5. "Euphos" globe, No. 72.

VISIBLE AND ULTRA-VIOLET SPECTRUM OF NERNST LAMP. (Exposure 20 min., showing effect of Euphos glass.)

study of arc-phenomena for example—some means of checking these rays effectually is very desirable. In this connection I might again refer to the work of Dr. W. Voege, who recently published an account of some interesting and useful researches on special spectacles intended to be used in this connection ("Elektrotechnische Zeitschrift," June 3rd, *Illuminating Engineer*, London, August, 1909). Dr. W. Voege finds that deep red glass is specially useful in this connection, when the loss of visible light so caused is of little consequence.

FIG. 93.


Visible Spectrum.
Ultra-Violet
Limit of Absorption for Ordinary Glass.
1. Osram lamp with clear bulb.
2. Osram lamp with "Euphos" bulb, 72.
3. Tantalum lamp with clear bulb.
4, Tantalum lamp with "Euphos" bulb, No. 71.
5. Colloidal metallic lamp clear globe.
6. Colloidal metallic lamp "Euphos" globe.

VISIBLE AND ULTRA-VIOLET SPECTRUM OF METALLIC FILAMENT LAMP. (Time of Exposure 20 min., showing effect of Euphos glass.)

A somewhat interesting case of the injuries which may apparently result from incautious exposure to ultra-violet radiation is furnished by some recent experiences of Dr. Bellile in the French Navy. (*Illuminating Engineer*, London, April, 1909.) This observer records the experiences of some wireless telegraphy operators on certain French battleships who suffered trouble from the eyes which was considered to be due to the ultra-violet light given out by the spark used in connection with the transmitting apparatus. However, as Dr. Voege has pointed out, further data are certainly necessary in order to determine more exactly the part played by the ultra-violet constituent in light used under ordinary practical conditions. It is for instance worth noting that according to medical authorities this ultra-violet constituent in sunlight is not without value on account of its supposed germicidal properties, and the free access of sunlight into interiors is regarded as one of the conditions which is most effective in counteracting the effect of any lurking tuberculosis bacilli.

CONCLUSION.

I now come to a few final remarks before winding up this course. If I have done nothing else in these lectures, I hope to have succeeded in giving you an idea of the vastness of this subject, and of the many different points of view that have to be taken into account, and the contradictory data which require to be reconciled. What is needed is a

man who shall be independent of any connection with any particular system of lighting, but who will take an impartial and unprejudiced view of them all, and therefore be capable of deciding to what case each particular illuminant is best applicable. In addition, such an expert must be a man of wide sympathies, not only willing and able to appreciate the economical and technical aspects of problems, but also in touch with the physiological and aesthetic aspects.

Such a man has yet to be evolved, and I have termed him "the expert illuminating engineer." I need not say that his development must be gradual, and his career for the present largely one of self-education.

It may perhaps seem to some of you that in parts of these lectures I have dwelt in a somewhat pessimistic manner on the defects of modern conditions of lighting, and harped too insistently on the many directions in which there is admittedly room for improvement. It must not be imagined, however, that I do not recognise that there has been most encouraging progress in certain respects, and that modern methods of illumination are in many ways a great advance on those in existence a few years ago. One of the most satisfactory indications of progress, perhaps, has been the steady growth of interest in matters of illuminating engineering; but what is now needed is to systematise and focus this interest to a greater extent, so that development may proceed on the proper lines. In dwelling on what remains to be done rather than on what has been done, therefore, I have been chiefly influenced by the desire to point out the necessity for such impartial and systematic effort, and the many fields in which substantial improvement might be made through the agency of an Illuminating Engineering Society and the illuminating expert engineer, whose development from existing professions such a society will, it is hoped, eventually bring about.

The urgent need at the present moment is for some method of bringing those interested in different aspects of illumination into one camp—a society which would enable them to appreciate each other's points of view, and would lead to mutual toleration and goodwill. In my paper read before the Society about three years ago, I referred to the need of the illuminating engineer, not dreaming at the time that the subject would have advanced so much as it has in this short period.

The time has now come for the formation of an Illuminating Engineering Society in this country. Many of you may know something of the immense progress and good work done by the society existing with this name in the United States. Since their start over three years ago, the number of members of this society has swelled from ninety-three to over 1,000.

At an informal dinner held on February 9th of this year it was decided to form a similar society in this country. Its object I have tried to explain to you, but I may repeat that all that is desired is a common impartial platform for the free discussion of these problems. Anyone interested in the subject is eligible as a member; at present, the membership will confer no professional status.

At a subsequent meeting on May 25th of this year, the draft-constitution of the society was formally adopted, and since that date the society has received influential support both in this country and on the Continent, from which I have just returned after hearing the views of the chief authorities on illumination, all of whom cordially approved our efforts. It is, I may mention, the intention to give the society as far as possible an international character, in order that concerted action may be taken in the future on matters of international importance.*

Before closing the lecture now, I feel that I ought to express my thanks and keen appreciation of the great kindness of the many who have assisted me, and to whose efforts any good results obtained are largely due.

I will, therefore, first of all, express my thanks to the very large number of manufacturers who have helped in exhibiting apparatus on such a generous scale.

These lectures may serve as an object-lesson to those who have contended that it is impossible for one man to gain the sympathy of those interested in all the different methods of illumination. I think that you will admit that I have at least tried to preserve an impartial attitude in delivering these lectures.

And next I must express my great indebtedness to the Royal Society of Arts for granting me such exceptional facilities in order to make the exhibition of these systems of lighting possible. I have been allowed the

* Anyone who would like to hear further particulars regarding this society is invited to apply to Mr. L. Gaster, Hon. Secretary, 32, Victoria-street, London, S.W.

privilege of introducing inflammable substances into this lecture theatre, to run piping, and to cause no little inconvenience by the constant stream of those engaged in the erection of the exhibits. This might be taken, however, as an indication that, with due precaution, all these systems can be regarded as safe methods of lighting and that there is room for the application of them all.

Thanks are due to Professor Stirling for the instructive series of slides and diagrams illustrating the construction of the eye, which he has kindly sent from Manchester University, and also to Professor J. T. Morris and Dr. C. V. Drysdale who have assisted in the same way. I should like in particular to express my appreciation of the services of my assistant, Mr. J. S. Dow, who has helped me throughout with the preparation of these lectures.

If I have inadvertedly omitted to make due reference to some apparatus, or did not devote enough time to some points on which fuller discussion may have been desirable, I can only plead the exceptionally wide scope of the subject.

Thanks are due to the following firms, who kindly exhibited apparatus shown in operation after the lectures :—

LECTURE I.

Glow Lamps.

Metallic filaments mostly using tungsten as chief material.

Messrs. Boddy and Co.—Board equipped with latest types of "Metalik" filament lamps.

The Bryant Trading Syndicate.—Board equipped with metallic filament lamps, including the 16 candle-power 20 watt 100-volt type, and a show-case indicating details of manufacture and materials used.

British Thomson-Houston Co., Ltd.—Exhibit of Tungsten incandescent lamps.

The Edison and Swan United Electric Light Co., Ltd.—Show-case containing different types and sizes of metallic filament lamps, including some in which the filament is mounted in an ordinary carbon glow-lamp bulb; also a carbon filament lamp of 1,000 candle-power, working at 100 volts.

The Electrical Co., Ltd.—Board equipped with "Aegma" metallic filament and a high candle-power; 200-volts Nernst lamps using 3 burners giving out 1,000 candle-power.

Messrs. Falk and Stadelmann, Ltd.—Exhibit of several "Sirius-Effesca" metallic filament lamps.

The General Electric Co., Ltd.—Board equipped with Osram lamps, including the tubular reflecting type; and a 400 candle-power lamp, mounted on a fixture used for inverted illumination.

Stearn Electric Co., Ltd.—Exhibit of Stearn "Leuconium" type of metallic filament lamps, burning several in series.

Sunbeam Co., Ltd.—Exhibit of metallic filament lamps.

The "Z" Electrical Syndicate.—A showcase containing the different types and sizes of metallic filament lamps.

Messrs. Siemens Bros., Ltd.—A board showing the latest designs of tantalum lamps and cluster of different designs using holophane globes and reflectors.

Messrs. Julius Sax and Co., Ltd.—Metallic filament lamps in connection with holophane glassware; one big holophane sphere installed for lighting up the main staircase of the Society.

Arc-Lamps and Mercury Vapour Lamps.

Messrs. Crompton and Co., Ltd.—Two Crompton-Blondel Arc-lamps.

The Jandus Arc-Lamp Co., Ltd.—Examples of Jandus enclosed and Jandus regenerative flame arc-lamps.

Marples, Leach and Co., Ltd.—Examples of Regina, Helia, and Reginula arc-lamps, and special photographic arc-lamps.

The Oliver Arc-Lamp Co., Ltd.—The Oriflame alternating current arc-lamp and magazine type.

The Union Electric Co., Ltd.—Duplex excello arc-lamps, provided with new prismatic inner globe, and special ventilation arrangement; alternating current arc-lamps and "Kohinoor" type lamps.

The Westinghouse Co., Ltd.—Mercury-vapour lamps of Cooper-Hewitt type, including the new "Static" type, by which instantaneous ignition is obtained without tilting the tube.

Mr. A. C. Cossor.—Specimens of fluorescent and phorescent materials excited by 5 milligrams of radium, and other apparatus.

Messrs. Isenthal and Co.—The "Uviol" mercury-vapour lamp.

LECTURE II.

High Candle-power Lamps.

The Chipperfield Lamp Syndicate, Ltd.—The Chipperfield self-intensifying lamp.

Messrs. R. Frister and Co. (Oberschöneweide, Berlin).—Example of the "Tubus" horizontal type of incandescent burner.

Messrs. Keith and Blackman, Ltd.—Complete model plant, comprising an electric motor and compressor to light the lamps exhibited, viz, one 1,500 candle-power high-pressure lamp, one 500 candle-power ditto, and one 150 candle-power ditto, fitted with automatic electric control and electric ignition.

Messrs. Moffat, Ltd.—The Lucas thermopile self-intensifying lamp.

Messrs. J. and W. B. Smith.—The Grätzin high-pressure lamp, three burners type, 4,500 candle-power; and the latest model compressing plant, comprising gas engine and compressor suitably mounted for exhibition.

New Types of Mantles and Burners

Messrs. Bland and Co.—Bland inverted burners.

Messrs. Falk and Stadelmann, Ltd.—The Vesta-Grätzin burners.

Messrs. G. Hands and Co.—The Hands patent cool inverted burner.

F. Mayer.—Self-lighting mantles.

Messrs. Moffat, Ltd.—"Mascot" and "Omar" inverted burners.

The Plaissetty Manufacturing Co., Ltd.—Various types of Monarch and other soft mantles.

The Herbert Tuchman Manufacturing Co.—"Reflex" inverted burners, small and larger types.

The Universal Gas Methane and Hella-Bushlight Co.—Examples of the Hella bushlight.

AUTOMATIC IGNITION SYSTEMS.

The Bland Light Syndicate, Ltd.—Pneumatic distance control.

Messrs. G. Hands and Co.—The Norwich system.

VARIOUS.

Schweiz, Flussiggas Fabrik L. Wolf, A. G.—The Wolff liquid-gas apparatus.

Messrs. Parkinson and Cowan, Ltd.—Exhibited an anti-vibrating device.

The Distance Lighting Co. showed the Bamag distance pressure-lighter and extinguisher for street lamps; and *Messrs. A. Lansberger* and *Dr. Rostin* exhibited the Rostin apparatus for the automatic control of public lights at a distance.

Special thanks must also be given to *Mr. F. W. Goodenough* and the *Gas Light and Coke Co.* for kindly putting at the lecturer's disposal the services of several fitters from the company's premises, and thus enabling the requisite piping for the exhibits to be laid at very short notice.

LECTURE III.

The Gas Economizing and Improved Light Syndicate, Ltd. (Blanchard System).—One 500 candle-power self-contained paraffin incandescent lamp fitted with inverted burner; one portable table lamp working on same system.

The United Kingdom Lighting Trust, Ltd.—Examples of latest type of Kitson Empire incandescent petroleum self-contained lamp of 1,000 candle-power, in actual operation.

Messrs. "Petrolite," Ltd. — Two examples of "Petrolite" petroleum incandescent lamps.

Messrs. Falk, Stadelmann and Co., Ltd.—Specimen of "Lucisca" portable petroleum incandescent lamp.

The Universal Gas Methane and "Buisson Hella" Co., Ltd.—Portable incandescent petroleum lamp fitted with "Hella Bushlight" mantle and burner.

The Machine Gas Syndicate (Cox's Air-Gas System).—Complete running plant in actual operation (estimated capacity 280 cubic feet per hour, 28 lights each consuming 10 cubic feet and yielding 125 candle-power), supplying air-gas to various burners, the gas being passed through piping immersed in a freezing mixture, with the object of demonstrating that there is no condensation.

The National Air Gas Co., Ltd. (Glascoe's Patent).—Exhibition of complete running plant in actual operation (20 burners of 50 candle-power or 40 of 25 candle-power, 100 cubic feet per hour estimated capacity), feeding various types of inverted and other incandescent mantles.

Messrs. Strode and Co. (Aerogen System).—Exhibition of complete running Aerogen plant in actual operation (estimated capacity, 35 burners, each consuming 2 cubic feet of gas, and yielding 25 candle-power), supplying petrol air gas to various inverted and other burners.

The Acetylene Illuminating Co., Ltd.—Complete dissolved acetylene outfit suitable for motor cars, lanterns, and other purposes; acetylene flashlight apparatus (Dalen patent); sun valve for automatically cutting off gas supply in daylight (Dalen patent); oxygen acetylene jet for lantern purposes; incandescent acetylene burners for motor head-lights, &c.

The Standard Acetylene Co —Complete generating plant for 30 burners of 20 candle-power, capacity of bell 10 cubic feet of gas; charge of carbide of 12 lb., water to carbide feed, supplying acetylene to series of elegant types of burners, in actual operation.

A specimen of non-combustible carborundum wick for use with spirit lamp, &c., the invention of Dr. B. Monasch, of Augsberg, was also on exhibition.

LECTURE IV.

The Bryant Trading Syndicate, Ltd.—Transformer for experimental purposes.

The Chloride Electrical Storage Co., Ltd.—Loan of a small battery of accumulators to supply current to Bechstein flicker photometer.

Messrs. Everett, Edgcumbe and Co., Ltd.—Example of Trotter Universal Photometer and portable "Watt-Photometer."

Messrs. Elliott Bros. — Example of Harrison Universal Photometer, adapted to measurements in a horizontal plane.

Messrs. Franz Schmidt and Haensch (Berlin).—Marten's illumination photometer, Thorner illumination tester, Bechstein flicker photometer (electrically driven), Bechstein contrast photometer.

The Gas Light and Coke Co. (*Mr. F. W. Goodenough*).—Series of incandescent gas lights equipped with various types of burners and shades for interior lighting.

The General Electric Co., Ltd.—Large type of multiple high candle-power metallic filament lamp fixture and single high candle-power Osram lamp fitting.

The Holophane Glass Co.—Examples of types of Holophane shades, shades and reflectors for use with gas and electric light fittings.

Messrs. Marples, Leach and Co., Ltd.—Regina Special arc-lamp for photographic purposes.

Messrs. Millar and Welch (Boston, U.S.A.).—The Williams "Simplex" Photometer.

Messrs. Gebr. Putzler (*Penzig, Schles., Germany*).—Specimen sheets of "Euphos" glass opaque to ultra-violet light, in four grades of opacity; examples of chimneys and glow-lamp bulbs composed of Euphos glass.

Messrs. Julius Sax and Co., Ltd.—Electric fittings and glassware for artistic decorative indoor illumination.

Messrs. W. Watson and Sons.—Fluorescent Barium platino-cyanide screen; samples of "Uviol" and "Uranium" glass; specimens of Jena flint glass opaque and transparent to ultra-violet rays respectively.

Special thanks are also due to *Drs. K. Stockhausen* and *F. Schanz, of Dresden*, the inventors of the "Euphos" glass, who kindly arranged for the exhibit of the specimens mentioned above, and also sent a series of lantern slides illustrating their properties; also to *Prof. Stirling*, *Prof. J. T. Morris*, and *Dr. C. Y. Drysdale*, for the loan of lantern slides.

Acknowledgement must also be made of the courtesy of the *City and Guilds of London Central Technical College* for kindly sanctioning the loan of some apparatus, including a photometrical bench, specimens of Uranium glass, &c.

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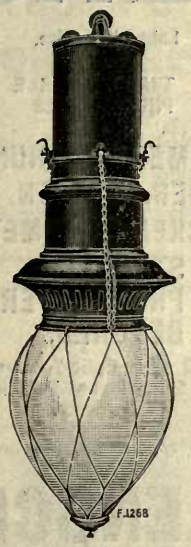

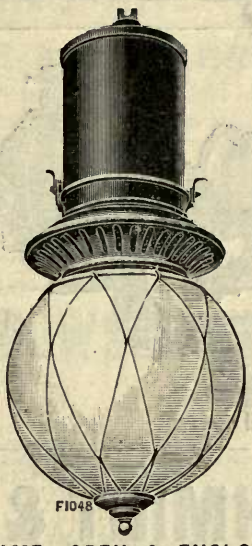

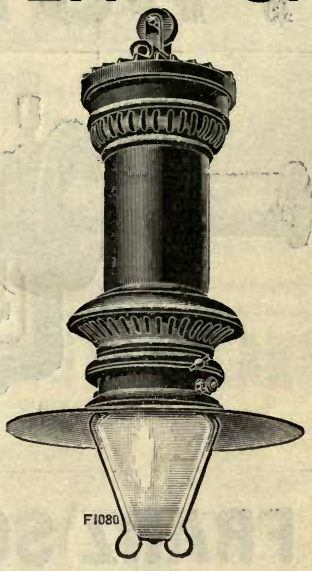

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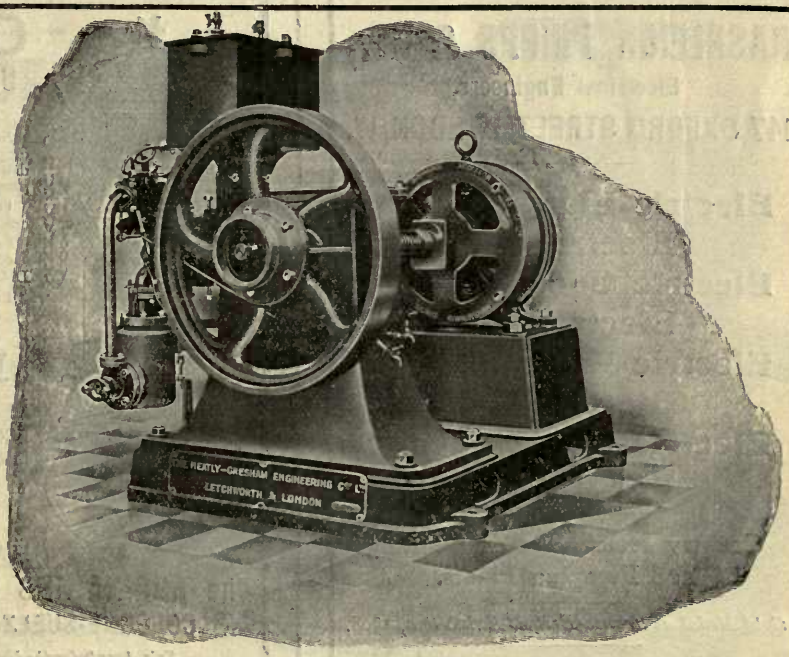

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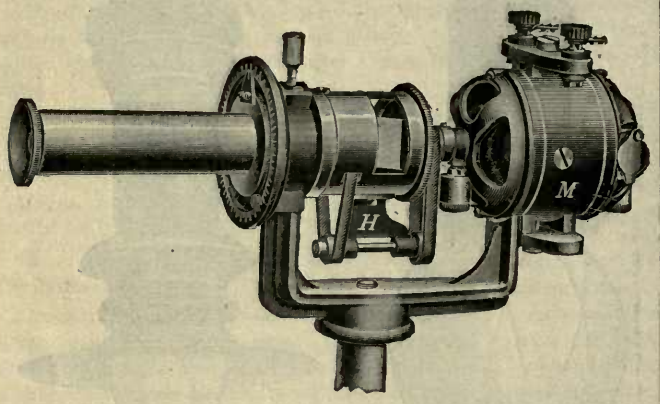

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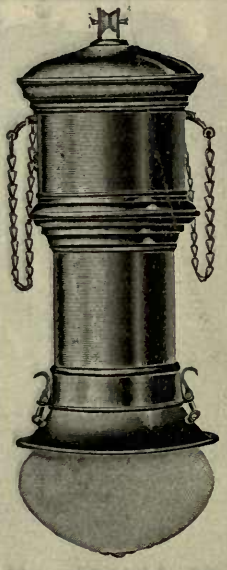

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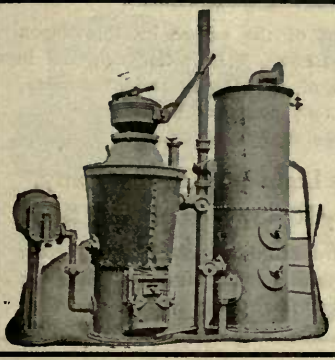

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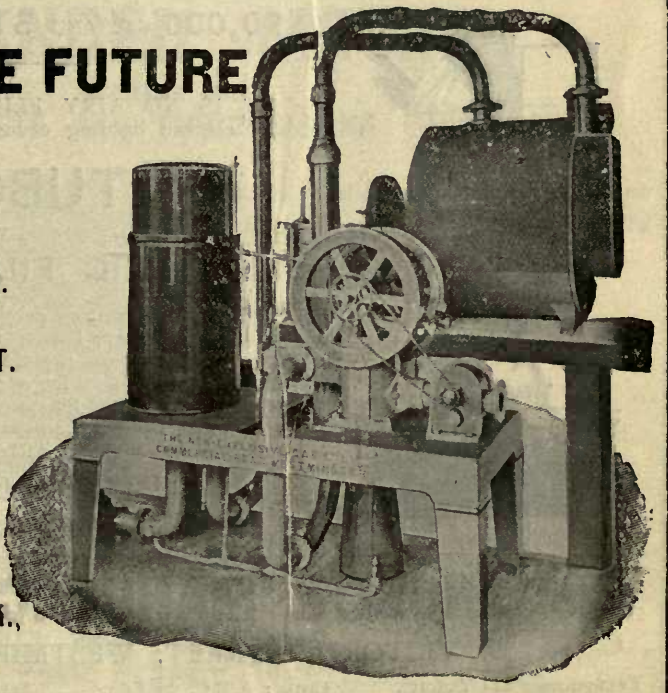

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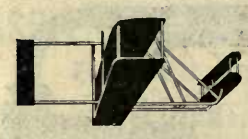

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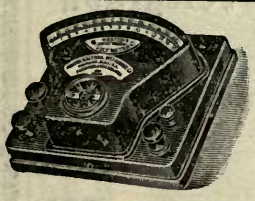

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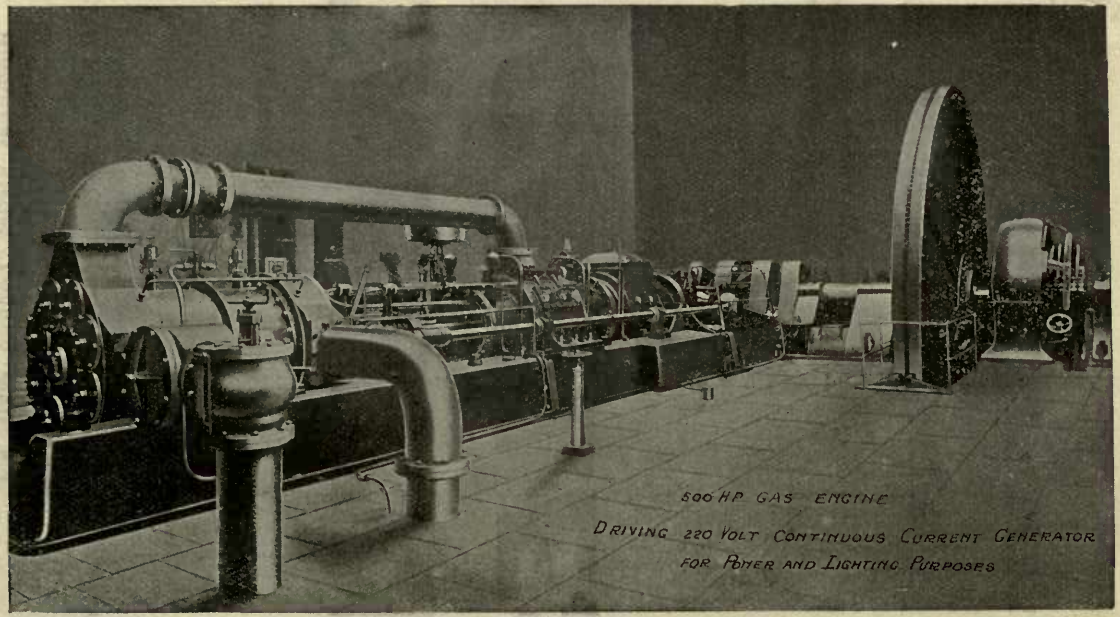

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